

Updating the environmental regulation of liquified CO₂ storage in ports to support carbon capture and storage plans in the UK

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Abstract

Carbon capture and storage (CCS) is central to the UK's Net-Zero Strategy, with shipping and ports playing a key role in enabling flexible CO₂ transport and storage (T&S) where pipelines infrastructure is not available. However, the regulation of the temporary storage of liquified CO₂ (LCO₂) in UK ports remains underexplored, particularly under the environmental permitting (England and Wales) Regulations 2016 (EPR).

In this paper, we critically assess the EPR's suitability for regulating temporary LCO₂ storage in ports in support of CCS. We examine the scope and limitations of the EPR's current CCS regime and explore whether other provisions can address the regulatory gaps that arise when storage occurs away from capture sites.

We identify key barriers that risk delaying the environmentally safe deployment of port-based LCO₂ storage. Our findings show that, while the EPR provides a solid foundation for environmental protection, it lacks the clarity and flexibility needed to address the regulatory complexities of shipping-based CCS and non-pipeline transport (NPT).

We propose targeted regulatory reforms to improve legal certainty, support infrastructure rollout, and align environmental safeguards with net-zero goals. Our analysis informs ongoing UK decarbonisation policy and highlights regulatory issues likely to emerge internationally as CO₂ shipping scales up.

Keywords

Environmental permitting (England and Wales) Regulations 2016, carbon capture and storage, non-pipeline transport (NPT), temporary CO₂ storage in ports, UK environmental law, port infrastructure regulation

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Introduction

Carbon capture and storage (CCS) is central to His Majesty's Government's (HMG) strategy to fulfil its legally binding target of achieving net-zero greenhouse gas (GHG) emissions by 2050 under the Climate Change Act 2008.¹ The Climate Change Committee (CCC)² described it as a 'necessity, not an option', stressing the importance of combining CCS deployment with broader efforts to cut emissions across energy, transport, industry, buildings, and agriculture.³

CCS projects vary significantly in their design, technical requirements, and implementation, depending on specific circumstances. These include the location of emission sources, the availability and nature of transport and storage infrastructure, the degree of coordination between participating actors, and the applicable legal and policy frameworks. Where pipeline infrastructure is not available or feasible, CCS deployment will depend on alternative transport solutions such as shipping,⁴ which is increasingly recognised as a critical component of flexible and scalable CCS networks.⁵

Ports will play a central role in enabling CCS projects that rely on shipping, while also facing new challenges from hosting activities such as CO₂ phase-change operations (e.g., liquefaction to prepare for transport), temporary storage, and ship loading and unloading. Some CO₂ may be captured at sea and delivered to receiving facilities in ports, while capture and conditioning infrastructure may also be located in ports, particularly given their proximity to major emitters. These operations give rise to a variety of regulatory questions relating to the different risks posed by the temporary storage of large volumes of CO₂ (>30,000 tCO₂) in ports. This includes questions about the extent to which these risks are governed by health and safety legislation and major accident prevention regulations, and by the environmental protection requirements set out in the Environmental Permitting (England and Wales) Regulations 2016 (EPR).⁶

¹ Climate Change Act 2008.

² The CCC is an independent statutory body which aims to advise the UK and devolved governments on emissions targets and to report to Parliament on progress made in reducing GHG and preparing for and adapting to the impacts of climate change. See About the Climate Change Committee at <https://www.theccc.org.uk/about/> (last visited 23 June 2025).

³ 'Sixth Carbon Budget' (Climate Change Committee, 2020) at <https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf> (last visited 23 June 2025). The CCC's stance aligns with the International Energy Agency's analysis of its most recent CCUS Projects Database, which found that current CCS deployment trends are inadequate for meeting mid-century net-zero targets. See M. Fajardy, C. Greenfield and J. Kodhuah, 'CCUS projects around the world are reaching new milestones' (IEA, 2025) at <https://www.iea.org/commentaries/ccus-projects-around-the-world-are-reaching-new-milestones> (last visited 23 June 2025).

⁴ 7CO₂: Severnside Carbon Capture & Shipping Hub at <https://www.7co2.co.uk/what-is-7co2> (last visited 23 June 2025); Harbour Energy, bp and Associated British Ports announce exclusive commercial agreement with Cory Group for CO₂ transportation and storage by ship, Viking CCS at https://www.vikingccs.co.uk/news/harbour-energy-bp-and-associated-british-ports-announce-exclusive-commercial-agreement-with-cory-group-for-co2-transportation-and-storage-by-ship?utm_source=chatgpt.com (last visited 23 June 2025); What We Do, Northern Lights at <https://norlights.com/what-we-do/> (last visited 23 June 2025); Building a European CCS Value Chain, Greensand at <https://greensandfuture.com/> (last visited 23 June 2025).

⁵ 'Industrial Decarbonisation: Getting Ready for Non-Pipeline Transport' (DNV, 2024) at <https://www.ukri.org/publications/industrial-decarbonisation-getting-ready-for-non-pipeline-transport/> (last visited 23 June 2025), chapter 5.

⁶ See W. Dbouk, DAH. Teagle, L-M. Armstrong, J. Hjalmarsson, S. Turnock and A. Ntovas, 'Critical review and recommendations for strengthening health and safety and major accident prevention regulations for carbon capture and storage in UK ports' (2025) 147 IJGGC 104479. Note that environmental permitting is a devolved matter in the UK. While the EPR apply in England and Wales, Scotland has its own regime under the Pollution Prevention and Control (Scotland) Regulations 2012 and the Environmental Authorisations (Scotland) Regulations 2018. The latter was recently amended to explicitly cover activities involving carbon capture and storage. Each regulatory framework applies within its own jurisdiction, and differences may be relevant where CCS shipping involves ports in different parts of the UK, such as the Acorn project in Scotland potentially receiving CO₂ from UK clusters. See 'Environmental Authorisations (Scotland) Amendment Regulations 2025: Final Business and Regulatory Impact Assessment' (Scottish Government, 2025) at (last visited 23 June 2025), 3, 5, 11, 14.

The EPR is key environmental protection regulations that came into force on 1 January 2017, replacing the Environmental Permitting (England and Wales) Regulations 2010 and consolidating various regulations aimed at achieving high levels of environmental protection.⁷ They establish a permitting system to protect human health and the environment by requiring licenses that comply with environmental standards and best practices (regulation 35 of the EPR), and apply to a wide range of industrial processes, waste operations, and polluting activities.

The EPR applies to ‘regulated facilities’. This includes installations carrying out listed activities, mobile plants, and certain water discharges (regulation 8 of the EPR; regulation 1(1), Part 1, Schedule 1 to the EPR). However, if an activity is not included in Schedule 1, a regulatory gap may arise. In complex processes involving multiple elements such as CCS, some components may be covered by the EPR while others are excluded. Such partial coverage can result in regulatory inconsistencies, creating significant challenges for operators and regulators in managing compliance and maintaining coherent environmental oversight.

Prompted by the adoption of the European Union Directive on the Geological Storage of Carbon Dioxide (2009/31/EC) (CCS Directive), CCS provisions were introduced to the EPR. These included provisions governing the injection of Carbon Dioxide (CO₂) streams into geological formations for the purpose of storage (paragraph 8(d), Schedule 22 to the EPR) and those regulating the capture of CO₂ streams as part of CCS (section 6.10, Chapter 6, Part 2, Schedule 1 to the EPR) (CCS-specific regime). However, the transport of CO₂ by ship in support of CCS was not considered within the scope of the CCS Directive. At the time of its adoption, the focus was on integrated full-chain projects located near major emitters, where pipeline transport was assumed to be the default. As a result, the CCS Directive addresses only pipeline transport and geological storage,⁸ leaving maritime CO₂ transport unregulated and creating significant gaps for ship-based CCS activities.

As ports become increasingly integral to CO₂ shipping chains in support of CCS, it is necessary to assess whether the EPR’s transposition of the CCS Directive extends to the regulation of *temporary CO₂ storage* therein.⁹ To explore this, we use a case study inspired by the Solent Industrial Cluster¹⁰ to critically examine the regulatory framework for such storage activities. We address two central questions:

1. Under what conditions does the CCS-specific regime apply to temporary storage activities in CCS projects relying on CO₂ shipping?
2. Where the EPR’s CCS-specific regime does not apply, can other EPR provisions – specifically those governing water discharge activities and waste management activities – fill this regulatory gap?

We begin by outlining our methodology for answering these questions and highlighting the research gap that our study contributes to filling. This is followed by an analysis of the EPR’s CCS-specific regime alongside its water discharge activities and waste management activities provisions, clarifying the conditions

⁷ This includes the now revoked Pollution Prevention and Control (England and Wales) Regulations 2000 (PPC), which aimed at achieving ‘a high level of protection of the environment as a whole’ by imposing a legal requirement on operators of risk-creating activities to adopt adequate measures to prevent or reduce emissions into the air, water and land (regulation 8(2) and (3) of the PPC)

⁸ See Article 3(22) of the CCS Directive, which defines ‘transport network’ as ‘the network of *pipelines*, including associated booster stations, for the transport of CO₂ to the storage site’ (emphasis added). See also Recital 38 of the CCS Directive.

⁹ EU Directives require Member States to meet core objectives and minimum standards, while allowing them to adopt more stringent or expansive measures provided these are compatible with EU law (a principle known as ‘minimum harmonisation’). See ‘European Union Directives’ (EUR-Lex, 2022) at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legisum:114527> (last visited 23 June 2025).

¹⁰ The Solent Cluster - Working towards a Lower Carbon Future at <https://www.thesolentcluster.com/> (last visited 23 June 2025).

under which these apply to temporary storage in ports as part of CCS. We then discuss the practical and policy implications of our analysis for the CCS scenario examined. We identify challenges and opportunities, and offer practical recommendations to resolve existing ambiguities in the EPR and enhance regulatory certainty to support safe CCS deployment. We conclude with a brief summary of key findings.

Methodology

To address the research questions outlined above, we conduct a comprehensive doctrinal analysis of the EPR, grounded in official guidance from relevant UK regulators and public bodies, and informed by academic and grey literature on environmental permitting and CCS, as well as relevant case-law, including European jurisprudence where applicable. To assess whether the EPR framework supports CCS development in ports, we explore the structure and flexibility of the permitting process, applying a legal realist approach to discuss how these rules function in practice. Particular attention is given to areas where ambiguity or inconsistency in the permitting process could delay or constrain CCS projects that rely on CO₂ shipping.

We situate our analysis within the UK's evolving CCS policy context, focusing on regulatory barriers that may hinder the safe deployment of CO₂ shipping infrastructure and considering implications for HMG's CCS plans. We pay particular attention to the regulation of temporary liquified CO₂ (LCO₂) storage in ports because it is a key aspect of shipping-based CO₂ transport – one of the non-pipeline transport (NPT) methods highlighted by the Department for Energy Security and Net Zero's (DESNZ) as essential for developing flexible and open access CO₂ transport and storage (T&S) networks in support of CCS.¹¹ LCO₂ is assumed to be the preferred form for temporary storage due to its high density and efficiency for onward transport.¹² By contrast, storing CO₂ in its supercritical or gaseous state is generally less practical due to the technical and energy requirements involved and the significant increase in storage volume or complexity such states would entail.¹³ It is also important to distinguish here between the treatment of CO₂ – where it is captured, purified, or liquified to make it transportable – and the preparation of CO₂ for transport, which focuses on the logistical, technical, and regulatory modifications required to safely and efficiently move the substance from capture sites to storage locations.

To ground our analysis, we use a case study informed by the Solent Local Industrial Decarbonisation Plan (LIDP) Transitioning Pathways report,¹⁴ which outlines potential decarbonisation routes for the Solent region. The LIDP report includes a CCS scenario centred on the Marchwood energy recovery facility and outlines three transport options for CO₂ to reach long-term sequestration sites.¹⁵ Notably, the shipping option is identified as critical for unlocking decarbonisation opportunities for smaller, more dispersed

¹¹ 'Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market' (DESNZ, 2023) at <https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-a-vision-to-establish-a-competitive-market> (last visited 23 June 2025), 41 ff (CCUS Vision). Within this context, a DESNZ call for evidence was launched on 7 May 2024 to help demonstrate NPT technically and commercially to reduce future costs, see 'CCUS: Non-Pipeline Transport and Cross-Border CO₂ Networks - Call for Evidence' (DESNZ, 2024) at <https://www.gov.uk/government/calls-for-evidence/carbon-capture-usage-and-storage-ccus-non-pipeline-transport-and-cross-border-co2-networks/ccus-non-pipeline-transport-and-cross-border-co2-networks-call-for-evidence> (last visited 23 June 2025).

¹² A. Sleiti and A-A. Wahib, 'CO₂ Transportation' [2022] *Emerging Carbon Capture Technologies* 279.

¹³ *ibid.*

¹⁴ 'The Solent Local Industrial Decarbonisation Plan (SOLENT LIDP) - Transitioning Pathways Version 1' (The Solent Cluster, 2025) at https://www.thesolentcluster.com/wp-content/uploads/2025/02/The_Solent_Cluster_LIDP_Roadmap_Brochure_UPDATED_ONLINE.pdf (last visited 23 June 2025).

¹⁵ *ibid.* 28.

emitters across southern England and Wales that face challenges with accessing local CO₂ storage.¹⁶ In this scenario, these emitters would transport CO₂ by rail to the port, where it would be liquified and temporarily stored before shipping. The proximity of rail infrastructure to the port underscores the port's crucial role as a hub for flexible, multimodal transport, enabling shared infrastructure and collaboration among smaller emitters to support CCS deployment in line with the HMG's CCS plans.¹⁷ Using a case study informed by the Marchwood facility example allows us to incorporate practical and policy considerations into our doctrinal analysis, reflecting on concrete plans to rely on CO₂ shipping for CCS in the UK.

Our case study centres on the scenario presented in Figure 1, where CO₂ is captured from multiple dispersed emitters, including small and medium-sized industrial facilities, and then transported by truck or rail (but also possibly by local pipelines or barges) to a port-based facility for conditioning, liquefaction, and temporary storage. From there, LCO₂ is transported by ship to a second port, where it is transferred to off-shore geological storage, either directly or via pipeline. Importantly, temporary storage will also be required at receiving ports with direct access to storage (e.g., the North-West and East Coast clusters) to enable the reception of CO₂ from regions without nearby storage capacity. This broader logistical function of ports, even within well-connected clusters, underscores the relevance of our scenario beyond the Solent region.

Our case study also differs from other CCS projects, including those that plan to use CO₂ shipping, in key respects. It reflects a situation where CO₂ is captured outside the port boundaries from geographically dispersed emitters, rather than at a single industrial site located within the port itself. These distinctions are important because they influence how the regulatory framework under the EPR applies. For example, the spatial separation between capture sites and liquefaction/storage facilities reveals challenges in how the EPR governs multi-operator, multi-site CCS chains involving non-pipeline transport. This highlights the inflexibility of the existing framework when applied to a type of CCS project being envisaged in the Solent Industrial Cluster.

This case-based approach enables us to highlight how regulatory design and implementation may affect the feasibility and environmentally safe scalability of CCS systems relying on CO₂ shipping in the UK, particularly for industrial clusters with limited or delayed access to pipeline transport. Our findings aim to inform both policymakers and operators seeking to navigate and improve the regulatory landscape for port-based CCS infrastructure in support of broader decarbonisation goals.

Research gap

Our study contributes to the academic literature on CO₂ T&S regulation, which has overlooked the role of temporary storage in ports within the broader CCS framework. Zakkour and Haines examined environmental protection and health and safety permitting regulations across different jurisdictions to identify regulatory gaps that could hinder CCS deployment.¹⁸ They acknowledged that the scale of CCS operations and the hazards associated with handling large quantities of CO₂ would introduce new risks that must be addressed in permit applications. They concluded that permitting systems for capture and transport required little modification, while 'major developments' would be needed for offshore geological storage, but omitted the shipping component from their analysis.¹⁹ They proposed that regulatory gaps could be resolved through adjustments or amendments to existing permitting regimes, an approach this article adopts by

¹⁶ S. Vakili, P. Manias, L-M. Armstrong, S. Turnock and DAH. Teagle, 'Technical, economic, and environmental assessment of CO₂ ship transport in carbon capture and storage' (2025) 373 JEL 123919.

¹⁷ Our regulatory analysis is confined to the EPR applicable in England and Wales. For details on the differing permitting regimes that would apply in other UK jurisdictions such as Scotland, see n 6 above.

¹⁸ P. Zakkour and M. Haines, 'Permitting Issues for CO₂ Capture, Transport and Geological Storage: A Review of Europe, USA, Canada and Australia' (2007) 1 IJGGC 94.

¹⁹ *ibid.*

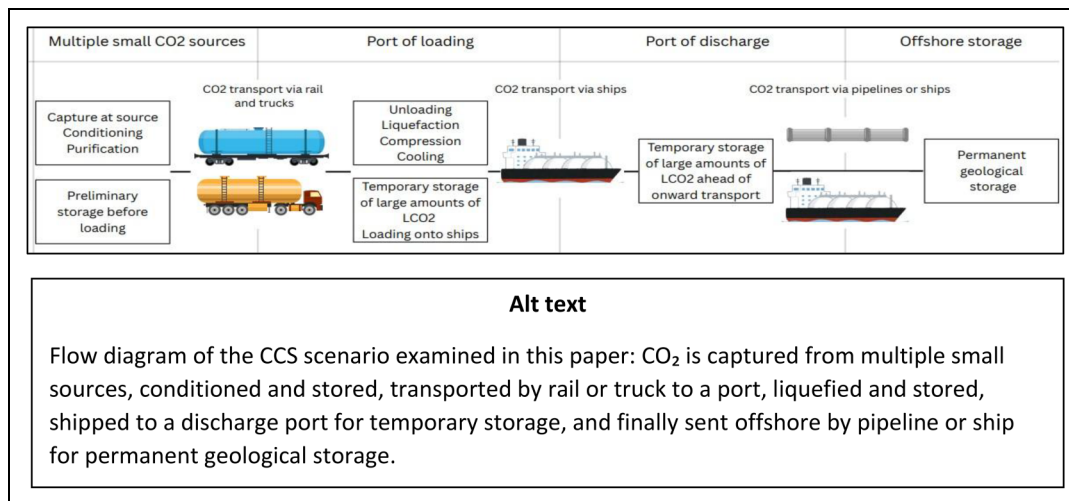


Figure 1. The CCS scenario examined in this paper.

focusing on the permitting requirements for LCO₂ storage in ports. Other literature analysed permitting requirements to understand how regulatory challenges influence CCS deployment. However, they focused only on offshore geological storage without considering scenarios requiring temporary storage in ports.^{20,21}

More specifically, our analysis of the EPR's applicability to CO₂ storage as 'waste' aligns with and expands on literature exploring how CO₂ classification affects CCS regulation across different legal frameworks. For instance, some studies assessed CO₂ classification in the context of international shipping regulations.²² This includes how classification affects the applicability of health and safety regulations such as the International Convention for the Safety of Life at Sea (SOLAS),²³ which, *inter alia*, establishes design requirements for CO₂-carrying ships, and liability frameworks like the Hazardous and Noxious Substances Convention.²⁴ These studies also discussed how regulatory aspects shape contractual arrangements for CO₂ shipping, influencing risk and liability allocation across the shipping chain, but failed to include temporary storage in ports within their scope.²⁵ Further research focused on the classification of CO₂ for its governance under frameworks for dumping at sea - particularly the London Convention, its 1996 Protocol, and related amendments -²⁶ or environmental protection frameworks such as the one established under the OPSAR

²⁰ N. Romasheva and A. Ilinova, 'CCS Projects: How Regulatory Framework Influences Their Deployment' (2019) 8 *Resources* 181.

²¹ G. Argüello and O. Bokareva, 'Transboundary Transportation of CO₂ Streams by Ships: Regulatory Barriers for Scaling up Carbon Capture and Sub-Seabed Storage' (2024) 11 *Frontiers in Marine Science* 1423962.

²² *ibid*; M. Roggenkamp, 'Transportation of Carbon Dioxide in the European Union: Some Legal Issues' in Ian Havercorft, Richard Macrory and Richard Stewart (eds), *Carbon Capture and Storage* (Hart Publishing Ltd 2018); M. Tsimplis and K. Noussia, 'The Use of Ships within a CCUS System: Regulation and Liability' (2022) 181 *Resources, Conservation and Recycling* 106218.

²³ International Convention for the Safety of Life at Sea (adopted 1 November 1974, entered into force 25 May 1980, London) 1184 UNTS 278.

²⁴ International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (adopted 3 May 1996, not yet in force) 35 ILM 1406, as amended by the Protocol of 2010 (adopted 30 April 2010, not yet in force); Argüello and Bokareva, n 21 above; Roggenkamp, n 22 above; Tsimplis and Noussia, n 22 above.

²⁵ Argüello and Bokareva, n 24 above; Roggenkamp, n 25 above; Tsimplis and Noussia, n 25 above.

²⁶ Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (adopted 29 December 1972, entered into force 30 August 1975) 1046 UNTS 120, as amended, and Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (adopted 7 November 1996, entered into force 24 March 2006).

Convention.²⁷ While this work is crucial for addressing uncertainties in the regulation of cross-border CCS under international dumping regimes, it has limited relevance for interpreting national regulations, including environmental permitting for temporary storage in ports. Lastly, some literature explored how CO₂ classification affects its transport via ships and pipelines under US law.²⁸ This body of work concluded that, overall, the USA is moving toward excluding CO₂ intended for capture, transport, and permanent storage from regulatory frameworks governing waste and pollutants.

While the existing literature has advanced our understanding of CCS regulation across various contexts, this paper adds a new dimension by offering a focused analysis of how the EPR applies to temporary LCO₂ storage in ports, an aspect that remains underexplored. By clarifying the applicability of the EPR's provisions through a detailed case study, this research addresses current regulatory ambiguities and provides practical insights to enable environmentally safe and flexible shipping-based CCS infrastructure. Furthermore, the analytical framework developed here can serve as a foundation for future comparative studies, supporting the development of best practices as more jurisdictions begin to address the permitting of CO₂ storage in ports.

Analysis

We structure our analysis in two parts. In sub-section i, we present the EPR's environmental protection approach, outlining how it addresses 'directly associated activities' and defines 'waste'. We intentionally introduce these foundational points at the outset to inform the analysis in sub-section ii. The concept of 'directly associated activities' is relevant to all the regulatory regimes examined in the second part. Similarly, because the definition of 'waste' varies across different EPR provisions, establishing it early allows for easy reference throughout the detailed analysis.

In sub-section ii, we examine the scope and conditions for regulating LCO₂ temporary storage activities in UK ports in support of CCS, specifically under the EPR's CCS-specific regime and the provisions relating to water discharge activities and waste management. This involves assessing how these provisions apply in this setting and identifying any regulatory gaps or overlaps, building on the framework established in the first part.

This approach minimises confusion and helps the reader navigate our nuanced regulatory analysis of the EPR, the practical and policy implications of which are then discussed in Section V.

Environmental permitting, the regulation of 'directly associated activities', and the definition of 'waste' under the EPR

The environmental permitting framework under the EPR. The EPR establishes the principal legal framework for regulating activities that could harm the environment or human health in England and Wales. Pursuant to

²⁷ Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) (adopted 22 September 1992, entered into force 25 March 1998) 2354 UNTS 67, as amended, including Annex V (adopted 23 July 1998) and amendments to Annexes II and III (adopted 18–22 June 2007); D. Henriksen and I. Ombudstvedt, 'Cross-Border Transportation – A Key to Unlock Full-Scale CCS' (2017) 114 *Energy Procedia* 7443; P. Marston and P. Moore, 'From EOR to CCS: the evolving legal and regulatory framework for carbon capture and storage' (2008) 29 *Energy Law Journal* 421; S. Gola and K. Noussia, 'From CO₂ sources to sinks: regulatory challenges for trans-boundary trade, shipment and storage' (2022) 179 *Resources, Conservation and Recycling* 106039; V. Weber, 'Are We Ready for the Ship Transport of CO₂ for CCS? Crude Solutions from International and European Law' (2021) 30 *RECIEL* 387.

²⁸ C. Arlota and M.B. Gerrard, 'Regulating Shipping of Carbon Dioxide for Sequestration' (2024) 54 *Environmental Law Reporter* 10837.

Part 2 of the EPR, operators of ‘regulated facilities’ must obtain an environmental permit prior to operating them and must for that purpose satisfy the competent authority of the conditions contained in that Part. This requirement also applies to those who intend to cause or knowingly permit water discharge activities (regulation 12(1)(b) of the EPR). The conditions for environmental permits include the adoption of measures to control emissions, prevent pollution, and mitigate potential environmental impacts associated with regulated facilities and with causing or knowingly permitting water discharge and groundwater activities. The specific conditions of environmental permits are set out by the regulator pursuant to paragraph 2(1), Part 1, Schedule 5 of the EPR. These conditions place the responsibility for managing environmental risks squarely on the operators of ‘regulated facilities’. For example, Part B1 of the EA’s environmental permit form for standard facilities requires applicants to have ‘an effective’ written environmental management system in place which satisfies the regulator that they have identified risks of pollution and taken appropriate measures to reduce them.²⁹

Part 4 of the EPR provides for the power of the competent authority to enforce the regulations by serving a notice on permit holders who have contravened or are likely to contravene any condition of their permit. The regulations also recognise the power of the competent authority to take action to prevent pollution or remedy it and then have recourse against the operator of the regulated facilities to recover the costs (regulation 57 of the EPR). In England, the competent authority under the EPR is either the EA or the local authority (as defined under regulation 6 of the EPR), depending on the description and class of the facility being regulated (regulation 32 of the EPR).³⁰

The EPR’s regime for ‘directly associated activities’. The EPR can also apply to installations where activities which are ‘directly associated’ with an activity listed in Part 2 of Schedule 1 thereto are undertaken (paragraph 1(2), Part 1, Schedule 1 to the EPR). This is a useful mechanism to expand the remit of the regulations beyond the activities which the regulator knows present a risk of environmental harm to cover essential supporting activities, ensuring comprehensive environmental oversight and preventing regulatory gaps in interconnected processes.

For an activity to be considered a ‘directly associated activity’, it must (1) have a technical connection with the main activity; (2) be carried out on the same site as the activity in question; and (3) present a risk of having an effect on pollution. When all three conditions are met, the operators of a given regulated facility would need to satisfy the regulator that they have also considered and adopted appropriate measures to control the risks posed by directly associated activities when applying for permits. This can be an indirect way of bringing CCS activities – including temporary storage – under the scope of the regulations without being explicitly included in their scope of application.

DEFRA’s ‘Industrial emissions Directive EPR Guidance on Part A installations’³¹ offers useful help for the interpretation of the ‘technical connection’ condition under paragraph 1(2), Part 1, Schedule 1 to the EPR.³² The combined reading of paragraphs 3.11–3.13 of the Guidance clarifies that the directly associated activity must ‘serve’ the installation where the main activity is undertaken in the sense that it contributes to

²⁹ ‘Application for an Environmental Permit: Part B1 Standard Facilities Permit’ (Environment Agency, 2025) at https://assets.publishing.service.gov.uk/media/67d2bf42886e7770c211e06a/Application_for_an_environmental_permit_Part_B1_standard_facilities_permit.pdf (last visited 23 June 2025).

³⁰ ‘Environmental Permitting Guidance: Core Guidance’ (Department for Environment, Food & Rural Affairs [DEFRA], 2020) at <https://assets.publishing.service.gov.uk/media/5fb3a39dd3bf7f37d7e7270e/environmental-permitting-core-guidance.pdf> (last visited 23 June 2025).

³¹ ‘Industrial emissions Directive EPR Guidance on Part A installations’ (DEFRA, 2013) <https://assets.publishing.service.gov.uk/media/5a7b8e02e5274a7318b8f6b3/pb13898-epr-guidance-part-a-130222.pdf> (last visited 26 June 2025).

³² The conditions for ‘directly associated activity’ is the same under both regulations.

the overall process of the main activity to which it is integral. In other words, the directly associated activity must enable the performance of the main activity which brings the installation where it is undertaken within the scope of the regulations. The Guidance highlights specific examples of instances where directly associated activities have a technical connection with the main activity being undertaken. The examples include ‘output activities’ that are concerned with the storage of the product of the regulated facility in question, and ‘intermediate activities’ which occur when the regulated facility consists of several ‘sub-units with the product of one sub-unit being stored or treated prior to being passed on to the next sub-unit in the production chain’. The former example brings the temporary storage of LCO₂ within the scope of the regulations as a product of CO₂ capture or liquefaction activities listed in Part 2 of Schedule 1 thereto, and the latter ensures that transport and intermediate storage are also regulated as CO₂ passes from the capture stage to the liquefaction stage as part of a process undertaken within the regulated facility.

Little guidance is offered in relation to the condition that the directly associated activity is undertaken on ‘the same site’ as the main activity in question. However, we can infer from the definition of ‘installation’ under paragraph 1(1), Part 1, Schedule 1 to the EPR that ‘stationary technical units’ where activities listed in Part 2 of Schedule 1 to the regulations are undertaken can be made up of several ‘locations’ where different directly associated activities can be performed to ‘serve’ the operation described by the main activity. In fact, in listing what constitutes an ‘installation’ under the regulations,³³ the paragraph distinguishes between *the* ‘stationary technical unit’ where ‘one or more’ Part 2 of Schedule 1 activities are carried out and *any other*’ (emphasis added) location ‘on the same site’ where directly associated activities are undertaken. We argue that ‘on the same site’ refers to the site of the ‘stationary technical unit’. For the regulations to expand to cover directly associated activities, the ‘locations’ where they are performed must be within the boundaries of the ‘stationary technical unit’ where the main activity in question is undertaken.

With regards to the condition that the directly associated activity must present a risk of having an effect on pollution, it is noted that regulation 2(1) of the EPR adopts a broad definition for ‘pollution’, with more specific definitions in relation to certain activities where appropriate (e.g., in relation to water discharge activities, as discussed below). Regulation 2(1) specifies that ‘pollution’ encompasses emissions into the air, water and land which present a risk of: (1) being harmful to human health or the quality of the environment, (2) impairing a human sense, (3) resulting in damage to material property, or (4) impeding or interfering with amenities or other legitimate uses of the environment. In 2002, the EA published guidelines to provide information on the most likely ‘potentially significant environmental effects’ of CCS activities to support developers and other proponents with meeting their requirements under applicable environmental impact assessment legislation.³⁴ The guidelines detail a non-exhaustive list of environmental risks posed by the different components of the CCS value chain, including harm to land, water, air and climate, ecology, and the human environment. The EA also produced a ‘quantitative environmental risk assessment for CCS’ to assist operators with identifying risks and reducing them to an acceptable level. It provided specific guidance on the risks to human health and the environment associated with the bulk storage and ship loading of LCO₂.³⁵ In addition to the risk of harm to animals and plants from cold gas or increased CO₂ concentration

³³ Which constitutes a type of ‘regulated facility’ governed by the EPR pursuant to regulation 8(1) of the EPR.

³⁴ ‘Scoping the Environmental Impacts of Carbon Capture, Transport and Storage’ (Environment Agency, 2002) <https://assets.publishing.service.gov.uk/media/5a7564f940f0b6360e473c6b/geho0811bucq-e-e.pdf> (last visited 23 June 2025).

³⁵ ‘Environmental risk assessment for carbon capture and storage 2011’ (Environment Agency, 2011) https://assets.publishing.service.gov.uk/media/66bcb67ec909b91981323def/Withdrawn__Environmental_risk_assessment_for_carbon_capture_and_storage_2011.pdf (last visited 25 September 2025). The guidance has been withdrawn on 14 August 2024, and replaced by the guidance ‘post-combustion carbon dioxide capture: emerging techniques’ and ‘hydrogen production with carbon capture: emerging techniques’. Neither of the new guidance include an assessment of the environmental risks associated with CCS. Instead, they assist proponents with understanding their duties under applicable regulations, including the EPR, and how to discharge them.

following an accidental release from these operations, the guidance warned of a ‘domino effect’ and the release of other substances. It assessed the consequences of such events as ‘high’ but, given their low likelihood, classified the overall risk as ‘medium’.³⁶ It is therefore arguable that temporary LCO₂ storage as part of CCS presents a risk of pollution to the environment, meeting the third condition under the EPR’s regime governing directly associated activities.

The definitions of ‘waste’ under the EPR. The EPR does not provide a single, uniform definition of ‘waste’. Instead, the regulations offer multiple definitions, each applicable to different activities they regulate. In doing so, the regulations reference more specific legislation related to those activities and, where necessary, departs from it.

‘Waste’ is defined pursuant to the Waste Framework Directive³⁷ (WFD) in relation to both water discharge activities outlined in Schedule 21 to the EPR and waste management activities described in Chapter 5 of Part 2 of Schedule 1 to the EPR (paragraph 2, Schedule 21 to the EPR; and regulation 2(1) of the EPR). It means ‘any substance or object which the holder discards or intends or is required to discard’ (Article 3(1) of the WFD). In other words, whether LCO₂ is considered ‘waste’ in relation to these activities depends on the actions, intentions, or obligations of the ‘waste holder’.³⁸

Article 3(6) of the WFD defines the ‘holder’ as ‘the producer of the waste or the natural or legal person who is in possession of it’. This definition is satisfied in two scenarios: (1) when the holder undertakes an activity which produces a substance or object which they intend to discard or are legally required to discard, i.e., a ‘producer of the waste’; and (2) when the holder is in possession of the waste after it becomes at their disposal and under their control through legal arrangements, such as contractual or administrative agreements with the producer of the waste in question, or with an intermediary in a longer chain of actors, i.e., ‘the natural or legal person in possession of the waste’.³⁹ The latter scenario includes situations where the holder enters into a service agreement for the temporary storage of the waste. In both cases, the ‘holder’ in possession of the waste bears an overarching duty to ensure compliance with any relevant legal or regulatory requirements governing its handling and storage.

Although the EPR draws on the WFD’s definition of ‘waste’, it introduces activity-specific exclusions, resulting in a definition that varies across different provisions. For example, in the case of water discharge activities, the definition excludes substances and objects listed under Article 2(1), 2(2), and 2(3) of the Directive. In contrast, for waste management activities, regulation 2(1) of the EPR excludes only those listed in Article 2(1)(d), which relates to radioactive waste. This means the definition of ‘waste’ is broader for waste management than for water discharge activities. Notably, it includes ‘gaseous effluents emitted into the atmosphere,’ which are excluded under Article 2(1)(a) of the WFD. This distinction is important when assessing how EPR provisions might apply to temporary CO₂ storage for CCS in ports, as discussed in the next sections.

³⁶ Ibid 37–38.

³⁷ Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance) [2008] OJ L312/3.

³⁸ J. Laziková and L. Rumanovská, ‘Waste in the EU Law’ (2024) 14 *Juridical Tribune - Review of Comparative and International Law* 260; R. Feltkamp and T. Hermans, ‘The (Legal) Concept of Waste an Obstacle for Circular Economy Activities (in the Brussels Capital Region)?’ 32:3 (2023) *EEELR* 114, 133; Case C-418/97 *ARCO Chemie Nederland Ltd v Minister van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* ECLI:EU:C:2000:318 (*ARCO Chemie*), 64 where the Court provided that ‘the method of treatment or use of a substance does not determine conclusively whether or not it is to be classified as waste’, adding that ‘[w]hat subsequently happens to an object or a substance does not affect its nature as waste, which [...] is defined in terms of the holder discarding it or intending or being required to discard it’.

³⁹ Laziková and Rumanovská, n 42 above; Feltkamp and T. Hermans, n 42 above.

The applicability of the EPR to LCO₂ storage as part of CCS in port settings

The question of the applicability of the EPR to LCO₂ storage activities in ports will determine if and under which conditions operators must implement measures to prevent environmental pollution from accidental releases. Notably, UK ports are operated and managed by Statutory Harbour Authorities (SHAs), which are responsible for ensuring safe and efficient port operations.⁴⁰ However, regulatory compliance for specific activities, such as handling and storage of hazardous substances, waste management or wastewater discharge, is the responsibility of the individual operators within the port, who must comply with applicable regulations such as the EPR and other industry-specific requirements.⁴¹

The EPR's regulation of LCO₂ storage under the CCS-specific regime. For a facility where a capture activity is undertaken to be regulated under the EPR's CCS-specific regime, the capture of CO₂ must be 'from an installation' and 'for the purpose of geological storage'. Whilst the CCS scenario considered in this paper satisfies the second of these conditions (see Figure 1), the first requires further clarification to explain how CO₂ capture relates to other EPR-regulated activities.

Under the EPR, an 'installation' is defined as 'a stationary technical unit where one or more activities are carried on' (paragraph 1, Part 1, Schedule 1 to the EPR), and 'activities' are those listed in Part 2 of Schedule 1. It follows that a CO₂ capture facility falls within scope only if it captures emissions from an installation engaged in one of these listed activities (such as energy production, metal processing, or chemical manufacturing).

Nevertheless, when the conditions of the CCS-specific regime are met, the regulation of a CO₂ capture facility could extend to include risks related to 'directly associated' storage activities, provided that such activities occur 'on the same site' and are technically connected. Each component of the CCS process is inherently linked and essential to achieving the overall goal of carbon sequestration, which the activity described in the CCS-specific regime pertains to.⁴² Conditioning, liquefaction and temporary LCO₂ storage are separate yet vital components of the broader CCS process, ensuring that captured CO₂ is safely contained and prepared for transportation or long-term sequestration. In this context, LCO₂ storage clearly functions as an 'output activity' that supports CO₂ capture, demonstrating the technical connection between the two activities.

However, determining whether LCO₂ storage takes place 'on the same site' as capture within a port presents challenges. First, it assumes that capture and conditioning/liquefaction are integrated within a single facility at the port. While this assumption holds when industrial emitters are located near CO₂ transport infrastructure,⁴³ it is not always the case in all CCS scenarios. For example, when small, dispersed emitters lack on-site liquefaction infrastructure, captured CO₂ is typically transported via pipelines, trucks, trains, or barges to a central facility in the port, where liquefaction and temporary storage occur before shipment or injection (which corresponds our examined scenario). Second, even when capture and conditioning/liquefaction are integrated into the same facility in the port, temporary storage must be part of the same operational system as the main activity to meet the condition.⁴⁴ If the storage occurs off-site or functions as part of a separate system, even within the same port, it will not qualify as a 'directly associated activity'

⁴⁰ Their respective powers, duties and geographical areas of jurisdiction are set out in local Acts of Parliament or Harbour Orders under the Harbours Act 1964 (in Great Britain) or the Harbours Act (Northern Ireland) 1970.

⁴¹ See the Port Marine Safety Code which clarifies the duties incumbent upon SHAs in the UK Department for Transport, 'Port Marine Safety Code' (Department for Transport, 2025) at <https://assets.publishing.service.gov.uk/media/67fd175bed87b81608546666/port-marine-safety-code.pdf> (last visited 23 June 2025).

⁴² Note the section's condition that CO₂ capture is 'for the purpose of geological storage'.

⁴³ The port of Immingham provides a good example, with several heavy industries and industrial activities taking place within its area - including oil refining and chemical manufacturing - and projects like HumberZero being expected to enable the capture of CO₂ emissions from such processes at point source. See Humber Zero Homepage at <https://humberzero.co.uk> (last visited 23 June 2025).

⁴⁴ See discussion on the definition of 'operator' under the EPR above.

under the regulations and must instead be regulated independently. Therefore, the extension of the regulation of capture facilities to temporary LCO₂ storage under the CCS-specific regime via the EPR's 'directly associated activities' regime is unlikely to apply in practice.

The regulation of LCO₂ storage under other EPR provisions

The water discharge activities regime. Water discharge activities are regulated under the EPR regardless of whether the installations from which they originate are covered by the regulations (regulation 8 of the EPR). In a CCS context, this could include water discharges from 'stationary technical units' in ports where LCO₂ is temporarily stored for onward shipping, even if these units are not covered by the CCS-specific regime. The applicability of the water discharge activities regime in this context is contingent on its scope of application, and on meeting specific conditions outlined in Schedule 21 – particularly, whether and under what conditions CO₂ is classified as 'waste'.

The definition of 'water discharge activity' under Schedule 21 to the EPR includes 'the discharge or entry to inland freshwaters, coastal waters, or relevant territorial waters' of, *inter alia*, 'waste matter' (paragraph 3(1)(a), Schedule 21 to the EPR). The EPR further defines 'pollution' in relation to water discharge activities as the 'direct or indirect' introduction, as a result of human activity, of substances, heat or biological entities or micro-organisms into the air, water or land which may cause harmful impacts on human health and water environments and terrestrial ecosystems directly depending on them, material damage to property, or interfere with amenities or other legitimate uses of the environment (regulation 2(1) of the EPR). Accordingly, the water discharge regime governs these forms of harm only insofar as they arise *via discharges into relevant waters*, and excludes scenarios where equivalent impacts occur independently through releases into the air or land.

'Waste' in 'waste matter' is defined by reference to the WFD, taking into account specific exclusions under Article 2. As previously discussed, this definition depends on the actions, intentions, or obligations of the 'waste holder', which includes both the 'waste producer' and 'the natural or legal person in possession of the waste' (paragraph 2, Schedule 21 to the EPR). Moreover, Schedule 21 to the EPR excludes substances listed under Article 2(1), 2(2), and 2(3) of the WFD from the definition of 'waste' in relation to water discharge activities. *Prima facie*, Article 2(1)(a) effectively prevents CO₂ emitted as a gaseous effluent from industrial processes⁴⁵ from qualifying as 'waste'. However, this exclusion applies specifically to 'gaseous effluents emitted into the atmosphere' (emphasis added), which does not apply when CO₂ is captured at source, as in CCS systems.⁴⁶ Moreover, Article 5 of the Directive and related communication from the European Commission⁴⁷ draw a clear distinction between 'waste' from 'by-products', based, *inter alia*, on the further utility of the substance in question.⁴⁸ Under Article 5.1 of the Directive, a substance may only be classified as a by-product if it results from a process whose 'primary aim' is *not* the production of that substance, and if its further use is certain.⁴⁹ Whereas the European Commission guidance considers materials whose use is not certain as 'waste', even if they were a *residue* of a production process

⁴⁵ Which climate change legislation specifically aims to mitigate.

⁴⁶ Feltkamp and T.Hermans, n 42 above, 18. The authors advance that the exclusion of 'gaseous effluents emitted into the atmosphere' from the scope of the WFD 'does not mean that they cannot ever be considered as waste', but rather that 'it simply implies that they are not to be considered as waste for the application of the WFD'.

⁴⁷ European Commission, 'Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on Waste and By-Products' COM (2007) 59 Final, 9, which in turn refers to relevant European Court of Justice case-law.

⁴⁸ Feltkamp and T.Hermans, n 42 above, 25.

⁴⁹ Article 5.1 lists three additional conditions for a substance to be considered a by-product. Since all of these conditions must be fulfilled for that classification, and given our argument that the 'further use' condition is not satisfied in the CCS context, we will not discuss the remaining conditions in this article.

from which they were deliberately produced (i.e., the production process was not modified in order to produce them).⁵⁰

The Article 5.1 conditions are not satisfied in a CCS context where the captured CO₂ is a *residue* of industrial activities with varying ‘primary aims’ (e.g., energy production, metal processing), and is intended for long-term geological storage⁵¹ rather than further use. This intention alone is enough to qualify the CO₂ as ‘waste’ under the WFD, and by extension, in relation to the EPR’s water discharge provisions. CO₂ capture and liquefaction are methods of treating the substance in question, and, in accordance with European case-law, these subsequent processes do not affect its nature as waste.⁵²

Operators of storage facilities that receive the LCO₂ take possession of this waste and assume control over it through legal arrangements with its ‘producers’⁵³ and/or other stakeholders in the CCS chain. This qualifies temporary storage operators as the ‘legal persons in possession of the waste’ (i.e., as ‘waste holders’) under the WFD, irrespective of whether the temporary storage occurs within or outside ports.

When applicable, the EPR’s water discharge regime safeguards against environmental pollution by prohibiting those causing or knowingly permitting water discharge activities from port facilities where LCO₂ is temporarily stored from doing so unless duly authorised by the competent authority (regulation 12(1) of the EPR).⁵⁴ The distinction between causing and knowingly permitting a water discharge is significant, as the latter relates to planned activities while the former also encompasses accidental or unplanned releases. As a result, the regime is relevant to the regulation of LCO₂ storage activities in ports in support of CCS in that it imposes duties on operators and other persons who control discharges⁵⁵ to prevent both planned and accidental discharges unless authorised by a permit, and, where unauthorised discharges occur from facilities under their control, to demonstrate that these do not give rise to the forms of water pollution governed by the regime within its applicable geographical scope. In contrast to the EPR’s CCS-specific regime, this environmental protection requirement applies regardless of where the capture or liquefaction processes occur or establishing that temporary storage is directly associated with them.

The EPR’s waste disposal regimes. Applying the EPR’s waste disposal provisions to temporary storage as part of CCS in ports depends on whether the captured CO₂ can be construed as ‘waste’ and on the interpretation of the activities which constitute ‘disposal’ under these provisions. If applicable, the classification of the waste as ‘hazardous’ or ‘non-hazardous’ also determines the environmental protection thresholds imposed for such activities, establishing two regimes that can apply within this context. The assessment of whether CO₂ is hazardous is carried out under the hazardous waste regime incorporated by the EPR, which draws on the technical criteria set out in Annex III of the WFD and, indirectly, on the classification rules under European Regulation (EC) No 1272/2008 on classification, labelling and packaging of

⁵⁰ European Commission, n 51 above, ‘Annex II - a decision tree for waste versus by-product decisions’, 13. In other words, according to the European Commission, not all residue substances are by-products.

⁵¹ It could also be argued that there is a *requirement* to discard it pursuant to climate mitigation provisions in applicable climate change legislation.

⁵² *ARCO Chemie*, n 42 above.

⁵³ Defined under Article 3.5 of the WFD as ‘anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste’.

⁵⁴ The Environment Agency in England or the Natural Resources Body for Wales in Wales (regulation 32 of the EPR).

⁵⁵ Those responsible do not need to operate the installation where the discharge occurs, as long as they retain control over the discharge activities themselves. This interpretation is supported by regulation 7 which considers that the expression ‘operate a regulated facility’ encompasses both (a) operating an installation and (b) carrying out water discharge activities, and defines ‘operator’ as the person who has ‘control over the operation of the regulated facility’.

substances and mixtures (CLP).⁵⁶ Waste which does not meet the applicable thresholds for classification as hazardous is, by default, treated as non-hazardous under that regime (regulation 1(2) of the EPR). The assessment of whether the applicable hazardous-waste thresholds are met falls outside the scope of this study; however, it should be noted that, although CO₂ is usually classified as a non-hazardous substance when transported and stored in relatively small quantities, this classification does not necessarily extend to its processing, handling, and storage in the larger volumes anticipated for extensive CCS activities (1–50 kt_{CO2}).⁵⁷

It is important to recall the definitions of ‘waste’ and ‘waste holder’ analysed earlier, along with the distinction between ‘waste’ and ‘by-products’ under the WFD. Taken together, these confirm that a substance is classified as ‘waste’ when it lacks further utility and is intended to be discarded, and that this classification is not altered by any subsequent treatment of the substance. This means that CO₂ produced by industrial activities such as fossil fuel-based energy generation qualifies as ‘waste’ where it has no further utility and is intended, or required by law, to be discarded. In such cases, the operator is considered the ‘producer’ of that waste under the EPR. Unlike the water discharge regime, the EPR explicitly includes gases released into the atmosphere within its definition of waste in relation to disposal activities. However, this inclusion is immaterial in the present context, since the same classification applies even where CO₂ is captured at source, as in the CCS scenarios considered here. The subsequent capture and liquefaction of CO₂ does not alter its status as waste, since it was initially intended to be discarded and had no further use. It continues to qualify as waste throughout the various stages of the CCS process, with the only change being that the role of ‘waste holder’ passes from the original ‘producer’ to the ‘legal person who is in possession’ of the CO₂.

The capture and liquefaction of CO₂ during the CCS process may constitute ‘waste disposal’ activities under the EPR. When they do, installations where such processes take place would fall within the scope of the regulations. This coverage would also include any temporary storage activities that meet the conditions for the ‘directly associated activities’ regime outlined above. However, only temporary storage that is directly associated with *liquefaction processes* would be relevant for the scenario considered in our paper, which is concerned specifically with the temporary storage of LCO₂ after liquefaction.

Sections 5.3 and 5.4 of Part 2 of Schedule 1 to the EPR (hereinafter ‘section 5.3’ and ‘section 5.4’) deal respectively with the disposal of hazardous and non-hazardous waste. ‘Disposal’ is defined in Schedule 9, which applies in relation to ‘every waste operation’ (paragraph 1, Schedule 9 to the EPR), by referring to the WFD. The latter does not condition the definition on the act of discarding the waste in question.⁵⁸ Rather, it defines ‘disposal’ as ‘*any* operation which is not recovery [...]’ (emphasis added) and provides examples of

⁵⁶ Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on Classification, Labelling and Packaging of Substances and Mixtures, Amending and Repealing Directives 67/548/EEC and 1999/45/EC, and Amending Regulation (EC) No 1907/2006 (Text with EEA Relevance) [2008] OJ L353/1. The Regulation is still in force in the UK today. See ‘Chemical Classification: The GB CLP Regulation’ (Health and Safety Executive, 2024) at <https://www.hse.gov.uk/chemical-classification/legal/clp-regulation.htm> (last visited 23 June 2025).

⁵⁷ Under the CLP Regulation, it is primarily the responsibility of manufacturers, importers, and downstream users to identify hazards and determine the appropriate classification of a substance, with competent authorities playing a supervisory role in overseeing compliance. The purpose for which these actors classify a given substance influences the settings in which the CLP-prescribed experiments for determining different hazard classes are conducted. In the case of CO₂, acute inhalation toxicity is typically assessed at benign atmospheric concentrations, rather than in mixtures that may contain more hazardous pollutants. Similarly, aquatic toxicity is generally tested using aqueous solutions, which may not accurately reflect the conditions under which liquified CO₂ could be released into the aquatic environment in CCS scenarios. For a more detailed analysis, see Wassim Dbouk, Damon Teagle, Alexandros Ntovas, Lindsay-Marie Armstrong and Stephen Turnock, ‘Review of the Legal and Regulatory Framework for CO₂ Shipping as Part of Carbon Capture and Storage in the United Kingdom’ (2024), University of Southampton <http://dx.doi.org/10.5258/SOTON/P1265> (last visited 25 September 2025), 75ff.

⁵⁸ This is consistent with the definition of ‘waste holder’ under the Directive which does not require them to be the person discarding the waste in question, as discussed below.

operations to which the definition apply in Annex I. ‘Recovery’ is defined as ‘any operation the principal result of which is waste serving a useful purpose [...]’ (Article 3.15 of the WFD). This excludes any scenario involving CO₂ when it is intended to be discarded permanently by injecting it under the seabed. The general definition of ‘disposal’ under the EPR therefore does not obstruct the application of their waste disposal provisions to the regulation of CCS activities. But this will depend on whether the specific conditions set out in those provisions are met. In this regard, sections 5.3 and 5.4 respectively outline the conditions for hazardous and non-hazardous waste disposal activities. Section 5.3 applies to hazardous waste disposal with a capacity exceeding 10 tonnes per day, while section 5.4 applies to non-hazardous waste disposal exceeding 50 tonnes per day.

A key requirement in both sections is that waste disposal is conducted at least in part through one of the activities *exhaustively* listed within them. Both sections notably include ‘physico-chemical treatment’ in their lists of covered disposal activities. The covers processes, in which the physical and/or chemical nature of the waste is altered or modified, provided the change is carried out for the purpose of disposal rather than mere transport or transfer. In other words, the waste must be subjected to treatment *in order to render it suitable for permanent disposal*. This interpretation is supported in UK case-law. In *United Utilities v Environment Agency*, Lord Rodger observed that physico-chemical treatment ‘which results in final compounds or mixtures which are discarded’ falls within the scope of disposal operations, distinguishing those from processes intended for recovery.⁵⁹ In that case, it was held that the treatment need not occur within the same installation as subsequent discard, so long as the treatment is properly linked to a disposal outcome.⁶⁰ Thus, even when treatment and discard occur in different facilities, the treatment may nevertheless qualify as a disposal activity if the treated end product is ultimately discarded.

By applying this lens to CO₂ in a CCS setting, the capture and liquefaction processes may qualify as physico-chemical treatment only if they alter the physical or chemical properties of CO₂ *for the purpose of disposal*. Thus, installations performing such treatment at scale may fall under the EPR’s disposal regimes if they exceed the relevant throughput thresholds (10 t/day for hazardous, 50 t/day for non-hazardous) and satisfy the linkage to a discard outcome.

Figure 2 below summarises the conditions for the application of the EPR’s waste disposal provisions to storage activities as part of CCS in UK ports.

The EPR temporary storage of waste regime. Section 5.6 of Part 2 of Schedule 1 (section 5.6) applies directly to the temporary storage of waste. It regulates installations where hazardous waste is temporarily stored with a total capacity exceeding 50 tonnes, provided such storage is ‘pending any of the [disposal] activities listed in sections 5.1 to 5.3 [...]’. This provision may apply to the post-liquefaction storage of LCO₂ in ports insofar as such storage precedes a disposal operation listed in section 5.3 that is integral to the CCS process.⁶¹ However, the analysis must also account for the explicit exclusion of ‘temporary storage, pending collection, on the site where the waste is generated’ from the section’s scope of application (section 5.6(a)(i), Part 2, Schedule 1 to the EPR).

Section 5.3 lists ‘physico-chemical treatment’ as one of the disposal activities it covers. As discussed above, this includes processes which alter the substance’s physical or chemical characteristics (e.g., phase change, impurity removal) to enable permanent disposal. In the next section, we will discuss how this

⁵⁹ *United Utilities plc v Environment Agency for England and Wales* [2007] UKHL 41, paras 5-8. Although the case was decided under the now-superseded Pollution Prevention and Control (England and Wales) Regulations 2000, its reasoning remains relevant because the concept of ‘physico-chemical treatment’ as a disposal operation has been retained in the EPR.

⁶⁰ *Ibid.*

⁶¹ sections 5.1 and 5.2 are excluded from our analysis, as they deal respectively with the incineration of waste and the disposal of waste by landfill.

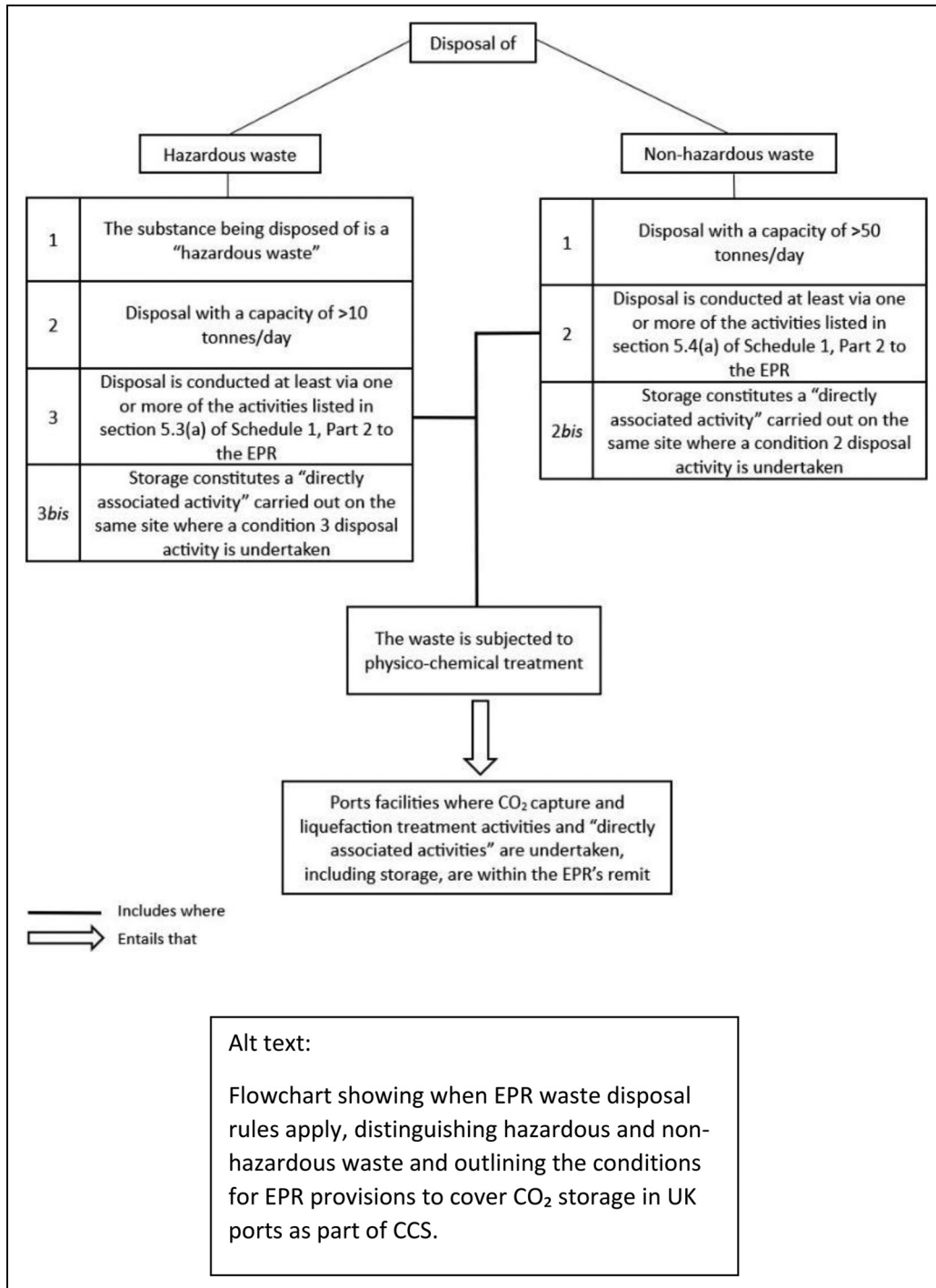


Figure 2. Proposed schematic summarising the conditions for the application of the EPR's waste disposal provisions to CO₂ storage activities as part of CCS in ports.

encompasses the treatment of CO₂ during capture and liquefaction as part of CCS, but excludes activities solely preparing it for transport, such as adjusting pressure, temperature, or handling conditions, which do not serve a disposal function. In practice, however, temporary storage pending capture does not occur when CO₂ is captured at point-source. This limits the potential application of section 5.6 to the temporary storage of already captured CO₂ pending its liquefaction, subject to the exclusion under section 5.6(a)(i) of Part 2 of Schedule 1 (section 5.6(a)(i)). Accordingly, where CO₂ is classified as hazardous waste and the tonnage threshold is exceeded, section 5.6 could apply to its temporary storage in compressed (gaseous or supercritical) form pending its treatment via liquefaction only, potentially bringing port installations involved in such storage within the EPR's scope.

However, unlike the WFD which explicitly includes disposal by 'sea-bed insertion' as operation D7 in Annex I, section 5.3 exhaustively defines disposal activities and omits this category. Consequently, temporary storage of LCO₂ pending permanent geological storage falls outside section 5.6's scope, as the EPR excludes such storage from its definition of 'disposal'.

For the section 5.6(a)(i) exclusion to apply, three conditions must be met: (1) the storage is temporary, (2) it precedes waste collection, and (3) it occurs on the site where the waste was generated. The WFD, which provides the underlying framework for the EPR's waste management regime, clarifies these conditions. Operation D15 in Annex I of the Directive mirrors section 5.6 of the EPR, including the exclusion under section 5.6(a)(i), albeit the Directive refers to the 'site where the waste is *produced*' (emphasis added), rather than 'generated' as phrased in the EPR.⁶² The footnote to operation D15 specifies that 'temporary storage' in this context means 'preliminary storage' as described in Article 3(10). In turn, Article 3(10) specifies that 'collection' means gathering the waste, and that 'gathering' involves the preliminary sorting and storage of the waste '*for the purposes of transport to a waste treatment facility*' (emphasis added).

Figure 3 below summarises the conditions for the application of the EPR's temporary storage of hazardous waste provisions to storage activities as part of CCS in UK ports.

Discussion

Practical implications for the EPR's regulation of temporary LCO₂ storage in UK ports

The EPR's CCS-specific regime. Our analysis reveals that the EPR's CCS-specific regime was designed to regulate CCS activities only within narrow parameters, primarily focusing on CO₂ capture for the purposes of geological storage. It does not address the increasingly complex operational realities of scaling up CCS infrastructure in the UK, particularly the critical roles that can be played by ports in CO₂ conditioning, liquefaction, and temporary storage. As a consequence, this regime leaves a clear regulatory gap: it neither explicitly encompasses the temporary storage of LCO₂ within ports nor adequately addresses the port's role in the broader CCS value chain.

This regulatory gap becomes especially apparent when assessed against the case study examined in this paper, which focuses on the post-liquefaction storage of LCO₂ in ports following the capture of CO₂ at dispersed industrial sites located outside the port. The CCS-specific regime applies only to facilities where capture activities are undertaken and may, under certain conditions, extend to govern activities 'directly associated' with that capture, including storage. However, in the scenario examined, capture and temporary storage occur at separate sites, preventing the latter from qualifying as 'directly associated'. As a result, even though temporary LCO₂ storage is functionally integral to the broader CCS process it enables, it falls outside the regime's scope, leaving this critical component unregulated. This creates a misalignment between

⁶² Which we argue are interchangeable terms for the purposes of our analysis.

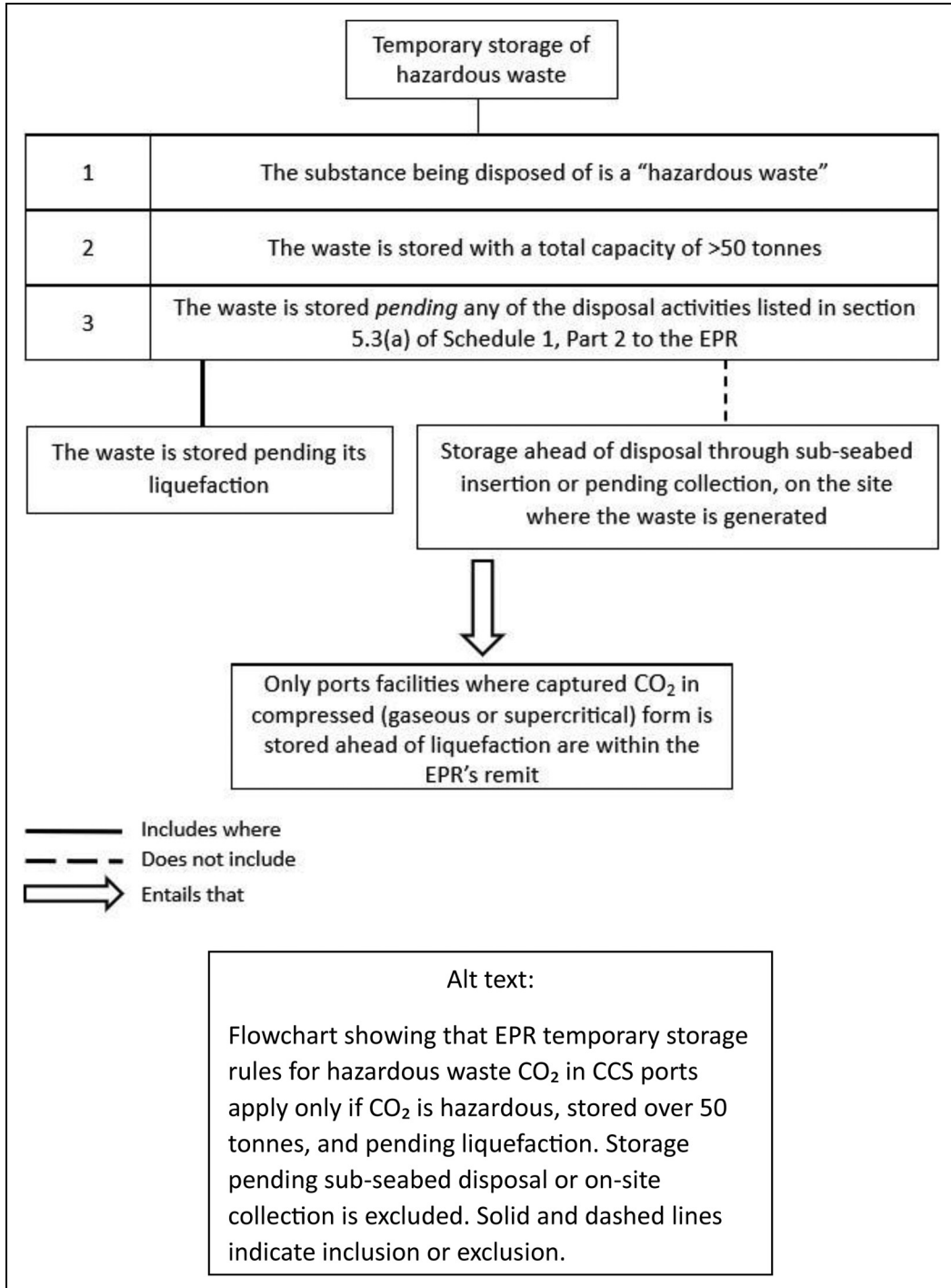


Figure 3. Proposed schematic summarising the conditions for the application of the EPR's temporary storage of hazardous waste provisions to CO₂ storage activities as part of CCS in ports.

the current regulatory framework and the logistical realities of the UK Government's planned CCS deployment (discussed below), particularly those involving centralised port-based handling and storage infrastructure.

In recognition of these limitations, we critically examine whether the EPR's waste provisions, specifically those governing water discharge activities, waste disposal activities, and temporary storage of waste, can fill this regulatory gap. Our discussion shows that while the definition of 'waste' under the EPR is broad enough to theoretically cover CCS-related LCO₂ storage activities, practical and legal constraints sharply limit the effectiveness of these provisions in regulating such activities.

The water discharge activities regime. First, the water discharge regime under Schedule 21 applies only to discharges of 'waste matter' into specified water bodies, namely inland freshwaters, coastal waters, or relevant territorial waters. The environmental protection it provides is also limited in scope, focusing primarily on preventing harm to aquatic ecosystems rather than offering comprehensive safeguards across environmental and operational dimensions.

Although the water discharge regime could, in principle, be invoked during the capture, transport, or temporary storage stages of the CCS case study examined in this paper,⁶³ its applicability would ultimately depend on the specific characteristics and location of the discharge. As analysed in section IV.ii above, the regime is confined to water discharge activities into specified waters and regulates pollution only where substances are introduced directly into those waters or indirectly into air or land via prior entry into those waters. By contrast, atmospheric or land-based releases of LCO₂ trigger environmental and safety risks outside this scope, including oxygen displacement by CO₂ vapour clouds from direct atmospheric release and cryogenic damage, overpressure, or jetting hazards from direct land contact. This limitation makes the water discharge regime unsuitable for regulating the full spectrum of pollution risks from port-based LCO₂ storage and for filling the regulatory gap discussed above.

The EPR's waste disposal regimes. Second, the application of the EPR's waste disposal provisions to temporary LCO₂ storage in ports depends on establishing that, in a CCS context: (1) the CO₂ being removed qualifies as 'waste';⁶⁴ (2) capture and liquefaction constitute 'physico-chemical treatment' of that waste; and (3) such storage is directly associated with the disposal of the waste via its treatment. Meeting these conditions is not straightforward, creating uncertainty and potential inconsistencies in the safety and environmental protection standards governing different components of the CCS process, particularly when the conditions are met in respect of some components but not others. The following paragraphs examine each of these conditions to assess the capacity of the EPR's waste disposal provisions to fill the regulatory gap left open by the CCS-specific regime.

1. Applying our analysis of the definition of 'waste' under the EPR's waste disposal provisions to our case study, we can conclude that the LCO₂ temporarily stored at the loading and receiving ports ahead of further transfer to permanent geological storage qualifies as 'waste' so long as it has no further utility and that its producer – i.e., the operator of the industrial activity being mitigated – intends to or is legally required to discard it. In this scenario, the operator of the temporary storage

⁶³ The regime's regulation of the discharge of waste matter cannot apply to the permanent geological storage component of the CCS process, which occurs offshore.

⁶⁴ The categorisation of CO₂ as 'hazardous' or 'non-hazardous' under applicable regulations falls outside the scope of this paper. This does not affect the discussion, as sections 5.3 and 5.4 (which apply respectively to hazardous and non-hazardous waste) have already been considered together in the analysis.

facility qualifies as the 'natural or legal person in possession' of the waste, having received CO₂ which has been captured from dispersed emitters (and conditioned/purified).

2. However, the qualification of capture and liquefaction processes as 'physico-chemical treatment' merits deeper scrutiny. We argue that the treatment of CO₂ during the capture and liquefaction processes fits within this category. In a CCS context, CO₂ capture methods, such as absorption, adsorption, membrane separation, and cryogenic separation, are designed to isolate CO₂ from gas streams. These methods inherently manipulate CO₂'s physical or chemical properties (e.g., chemical solvents in absorption, molecular sieves in adsorption). Similarly, the liquefaction process, which involves compression and cooling, focuses on phase change (gas to liquid) and purity (removing impurities like water or sulphur). While these processes incidentally facilitate efficient transport and storage, their primary regulatory purpose under section 5.3 is to prepare CO₂ for permanent disposal, not transport. This differs from downstream transport adjustments, which modify pressure, temperature, or handling conditions (e.g., cryogenic storage tanks, pipeline retrofitting) to enable safe, efficient multi-modal transfer. Such adjustments do not alter CO₂'s composition and therefore fall outside the definition of 'physico-chemical treatment' under sections 5.3 and 5.4. Therefore, installations may fall within the scope of the EPR under the waste disposal regimes of sections 5.3 or 5.4 if they are used to 'treat' CO₂ through activities involved in the capture and liquefaction processes at a capacity exceeding 10 tonnes per day for hazardous waste, or 50 tonnes per day for non-hazardous waste.
3. As discussed above, the EPR's CCS-specific regime may extend to regulate port-based LCO₂ storage activities only if the CO₂ capture activity also occurs on the same site. In this respect, the waste disposal provisions arguably add limited regulatory value by covering installations where capture takes place. It creates potential overlap or competition with the more relevant CCS-specific regime, which applies directly to CO₂ capture without imposing the additional conditions required for waste disposal activities. However, since in our examined scenario CO₂ is captured from multiple emitters outside port boundaries, neither regime effectively regulates LCO₂ storage in ports.

Nevertheless, the waste disposal provisions can govern ports where temporary LCO₂ storage occurs as an activity directly associated with liquefaction, regardless of where capture takes place. Here, the activities are 'technically connected', as temporary storage constitutes an 'output activity' that 'serves' the disposal of CO₂ through liquefaction. This interpretation aligns with the essential role of temporary storage in safely containing and preparing CO₂ for onward transport or permanent sequestration within the CCS chain.

Provided that storage activities fall within the 'stationary technical unit' performing CO₂ disposal via liquefaction, and considering the environmental pollution risks outlined above, the conditions for applying the EPR's regime to 'directly associated activities' would be satisfied. Unlike the regime under section 5.6 (discussed below), such storage need not precede the disposal activity regulated, nor is it subject to specific tonnage thresholds; as the threshold applies to the associated disposal activity.

It is important to recall that in our scenario examined, temporary LCO₂ storage occurs at both loading and receiving ports, with ships transporting the LCO₂ between them. Given this setup, extending the section 5.3 and 5.4 regimes to regulate temporary storage at receiving ports would not be possible. At the receiving port, the liquefaction process will already have been completed at the loading port, so liquefaction and temporary storage do not occur on the same site. As a result, these activities at the receiving port cannot be considered 'directly associated activities' under the EPR, creating a further regulatory inconsistency at the receiving end of CCS transport chains.

It follows that the applicability of the EPR's waste disposal provisions to port-based LCO₂ storage depends not only on the physical integration of storage with liquefaction facilities but also on the unresolved question of whether liquefaction qualifies as a waste disposal activity through 'physico-chemical treatment'.

This interpretation is yet to be established by regulatory authorities or supported in case-law. Consequently, the regime's ability to address the regulatory gap for LCO₂ storage in ports remains both limited and uncertain, particularly at receiving ports where upstream treatment activities have been carried out elsewhere, as in the case study considered in this paper.

The EPR's temporary storage of waste regime. Third, the EPR's regime for regulating the temporary storage of hazardous waste applies when such storage occurs pending one or more of the disposal activities listed in section 5.3, which includes 'physico-chemical treatment'. However, the regime does not apply to 'temporary storage, pending collection, on the site where the waste is generated' (excluded under section 5.6(a)(i)). Nor does it govern storage pending 'sea-bed insertion'.⁶⁵ The regime also applies only to hazardous waste, meaning that CO₂ must be classified as such for storage above at a capacity exceeding 50 tonnes to fall within its scope. These limitations significantly restrict the regime's applicability in the scenario under consideration in our case study.

As previously discussed, 'physico-chemical treatment' includes processes integral to the capture and liquefaction of CO₂ which alter the substance's physical or chemical characteristics (e.g., phase change, impurity removal) to enable permanent disposal. However, temporary storage pending capture does not occur in practice where CO₂ is captured at point-source. This limits section 5.6's relevance to the temporary storage of already captured CO₂ awaiting liquefaction. In this regard, based on our analysis above, we argue that the conditions for the exclusion under section 5.6(a)(i) are satisfied when CO₂ is captured at the point of emission (i.e., the site where the waste was 'generated'), then stored temporarily on the same site before being collected by truck or rail from dispersed emitters for transfer to a liquefaction facility. This further narrows the applicability of the regime during the capture stage of the CCS process in our examined scenario, excluding it from governing the temporary storage of captured CO₂ prior to its loading for transport to port-based liquefaction facilities.

Moreover, while the regime may govern the pre-liquefaction storage of CO₂ arriving at ports in compressed (gaseous or supercritical) form,⁶⁶ it does not apply in the examined scenario, where the LCO₂ is stored *post-liquefaction* at the loading port and requires no further treatment beyond preparation for onward transport. Similarly, LCO₂ at the destination port is temporarily stored pending transfer to offshore storage. It does not need to be processed further beyond preparing it for transport through adjusting pressure, temperature, or handling conditions. These activities serve no disposal function and do not qualify as 'physico-chemical treatment' under section 5.3. Temporary storage preceding them does not fall within the scope of the section 5.6 regime.

The omission of seabed insertion from the list of disposal operations under section 5.3, combined with the exclusion of pre-transport storage from section 5.6,⁶⁷ leaves temporary post-liquefaction storage of LCO₂ in ports outside the scope of EPR's temporary storage of hazardous waste regime. These activities which are logistically critical to the CCS scenario examined in our case study are neither governed by waste

⁶⁵ The omission of 'sea-bed insertion' from the list of disposal activities covered by section 5.3 reflects HMG's choice to regulate offshore CCS through the licensing and permitting regime under the Energy Act 2008, administered by the North Sea Transition Authority (NSTA). The NSTA is complemented by the Crown Estate's power to grant leases for developers to access seabed rights, the Offshore Petroleum Regulator for Environment and Decommissioning's (OPRED) oversight of assessments under the Habitats Regulations for activities affecting protected marine sites, and the Office of Gas and Electricity Markets' (Ofgem) role in regulating CO₂ transport and storage networks under the Energy Security Bill; see Dbouk *et al.*, n 61 above, 92 ff.

⁶⁶ Depending on the specifics of the CCS project in question, usually either in buffer tanks or in intermediate high-pressure storage vessels, in order to ensure a steady feed into the liquefaction process.

⁶⁷ Which is excluded partly by the exclusion under section 5.6(a)(i) and as a result of section 5.6 applying only to storage pending listed disposal activities (as opposed to further transport).

disposal regulations nor covered under the offshore licensing regime, which applies only to offshore geological storage and does not extend to onshore or port-based infrastructure,⁶⁸ leaving their oversight fragmented and incomplete.⁶⁹ Uncertainty over whether liquefaction qualifies as a disposal activity further undermines the regime's potential to govern LCO₂ storage prior to the liquefaction process. It follows that section 5.6 does not offer a reliable or comprehensive legal basis for regulating LCO₂ storage in support of CCS, especially when such storage occurs at ports ahead of offshore injection.

In conclusion, the EPR's CCS-specific regime fails to regulate temporary LCO₂ storage at ports because it ties permitting requirements solely to the location of capture activities, excluding downstream storage and handling. In the case study examined, where CO₂ is captured from multiple dispersed emitters and then transported to a separate port facility for conditioning, liquefaction, and temporary storage, the legal design of the CCS-specific regime prevents its extension to cover storage activities. Since these activities occur on a different site from where capture takes place, they do not qualify as 'directly associated', placing them outside the scope of the regime. This legal design flaw creates a significant regulatory blind spot for port-based logistics that are integral to HMG's approach to scaling CCS networks via NPT. As a result, a critical component of the CO₂ T&S process escapes environmental permitting altogether, weakening the coherence and integrity of the UK's CCS governance framework. This regulatory gap cannot be addressed by relying on the EPR's waste-related provisions governing water discharges, waste disposal, and temporary storage. Each of these provisions is subject to practical and legal constraints that sharply limit their applicability to post-liquefaction LCO₂ storage in ports. These limitations include narrow territorial scopes, definitional ambiguities around 'physico-chemical treatment', and preconditions that exclude essential CCS logistics from regulatory coverage, potentially resulting in inconsistent oversight across different components of the CCS process.

To resolve these shortcomings, legislative reform is needed to establish a coherent and unified regulatory basis that brings CCS-related activities under a fit-for-purpose permitting regime. In particular, the framework must recognise that temporary storage, including post-liquefaction LCO₂ held at ports prior to maritime transport, constitutes a core element of non-pipeline transport infrastructure rather than a peripheral or incidental activity. Without such recognition, critical operations may continue to fall outside the scope of the EPR, undermining regulatory certainty and weakening environmental safeguards. In the next section, we present recommendations to inform how the regulatory gap in temporary LCO₂ storage at ports discussed here can be effectively addressed.

Policy implications and recommendations

The UK Government's net-zero commitments are underpinned by a suite of strategies and legislative frameworks, including the Net-Zero Strategy,⁷⁰ the Ten Point Plan,⁷¹ the Industrial Decarbonisation

⁶⁸ Although the offshore CCS licensing regime under the Storage of Carbon Dioxide (Licensing etc.) Regulations 2010 governs CO₂ storage in the 'offshore area' as defined under the Energy Act 2008, its scope does not extend to onshore infrastructure or port-based activities such as temporary storage prior to injection. The 2010 Regulations exclude territorial waters adjacent to Scotland and were initially limited to activities taking place beyond the territorial sea. While the Storage of Carbon Dioxide (Amendment of the Energy Act 2008) Regulations 2011 expanded the definition of 'controlled place' in section 17 of the Energy Act to include internal waters of England, Wales, and Northern Ireland, this amendment does not alter the limited scope of the 2010 Regulations themselves, which still do not govern onshore or port-based LCO₂ storage.

⁶⁹ Dbouk *et al*, n 61 above, 92 ff.

⁷⁰ 'Net-Zero Strategy: Build Back Greener' (DESNZ, 2021) at <https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf> (last visited 23 June 2025).

⁷¹ 'The Ten Point Plan for a Green Industrial Revolution' (Department for Business, Energy & Industrial Strategy [BEIS], 2020) https://assets.publishing.service.gov.uk/media/5fb5513de90e0720978b1a6f/10_POINT_PLAN_BOOKLET.pdf (last visited 23 June 2025).

Strategy,⁷² and the Energy Act 2023.⁷³ Collectively, these support the CCC's view that CCS as essential to achieving the UK's climate targets, aiming to capture and store 20–30 million tonnes of CO₂ annually by 2030 through six industrial clusters. While pipeline infrastructure will serve many of these clusters, a significant share of emissions lies outside these hubs,⁷⁴ requiring an expanded and accessible T&S network. Shipping has emerged as a flexible, cost-effective transport solution, particularly for shoreline clusters lacking feasible pipeline access, with ports becoming critical nodes for CO₂ handling, liquefaction, temporary storage, and transfer.⁷⁵ This applies to the prospective transport of CO₂ from the Solent Industrial Cluster, with the geostorage options to be initially developed in the North or Irish Seas more than 400 km away, in light of challenges in unlocking storage potential in the English Channel⁷⁶ (see Figure 4).⁷⁷

Despite clear policy support for CCS,⁷⁸ our case study demonstrates that HMG's environmental regulatory framework has not kept pace with the increasing complexity and diversity of CCS project configurations, leaving it misaligned with current policy objectives. As explained in section II, the scenario examined was selected to illustrate the emerging role of ports as critical infrastructure for enabling CCS deployment across dispersed industrial regions, using the Solent Industrial Cluster as an example. This includes activities such as CO₂ conditioning, liquefaction, temporary storage, and transfer in support of shipping. These functions raise new regulatory challenges, particularly in relation to environmental risk management, due to the scale and nature of CO₂ handling and storage at ports.

Our case study specifically examined the regulation of LCO₂ storage in ports in support of CCS, focusing on the adequacy of the existing environmental permitting framework. The CCS-specific permitting regime applies only to capture activities and directly associated storage occurring on the same site, leaving a clear regulatory gap in cases where capture and post-liquefaction storage occur on different sites. This gap cannot be readily addressed by reference to other provisions under the EPR. The water discharge and waste-management provisions either offer limited regulatory coverage or depend on unestablished classifications, which create significant uncertainty around their invocation in this context. As a result, port-based LCO₂ storage activities fall outside a dedicated permitting framework, leading to overlapping or inconsistent regulatory obligations and significant

⁷² 'Industrial Decarbonisation Strategy' (BEIS, 2021) https://assets.publishing.service.gov.uk/media/6051cd04e90e07527f645f1e/Industrial_Decarbonisation_Strategy_March_2021.pdf (last visited 23 June 2025).

⁷³ Energy Act 2023.

⁷⁴ 'Carbon Capture, Usage and Storage (CCUS) - Call for Evidence on Non-Pipeline Transport and Cross-Border CO₂ Networks' (DESNZ, 2024) at https://assets.publishing.service.gov.uk/media/663511c24d8bb7378fb6c271/ccus-non-pipeline-transport-cross-border-co2-networks-call-for-evidence.pdf?utm_source=chatgpt.com (last visited 23 June 2025), 8, which refers to 'Cluster Sequencing for Carbon Capture, Usage and Storage (CCUS): Track-2 Guidance' (DESNZ, 2023) at <https://assets.publishing.service.gov.uk/media/6426adfdfbe620000c17da0e/cluster-sequencing-for-ccus-track-2-guidance.pdf> (last visited 23 June 2025) to note that around half of the industrial emissions in the UK are produced outside industrial clusters.

⁷⁵ 'Deep-Decarbonisation Pathways for UK Industry - a Report for the Climate Change Committee' (Element Energy, 2020) at <https://www.theccc.org.uk/publication/deep-decarbonisation-pathways-for-uk-industry-element-energy/> (last visited 23 June 2025).

⁷⁶ Emily Ford, 'ExxonMobil: Firm Backs out of CO₂ Pipeline Project' *BBC News* 3 October 2024 at <https://www.bbc.co.uk/news/articles/c4glw4dyw8no> (last visited 23 June 2025).

⁷⁷ BEIS, n 73 above.

⁷⁸ Substantial government funding has bolstered confidence in CCS plans, signalling a continuity in policy support and underscoring the strategic importance of CCS in the UK's industrial decarbonisation efforts. See 'Government Provides a Springboard to UK CCUS Industry with £20 Billion for Early Deployment' *CCSA* 15 March 2023 at <https://www.ccsassociation.org/all-news/ccsa-news/government-launches-uk-ccus-industry-with-20-billion-for-early-deployment/> (last visited 23 June 2025); 'Change' (The Labour Party, 2024) at <https://labour.org.uk/change/my-plan-for-change/> (last visited 23 June 2025); HC Deb vol 754 col 65-81 7 October 2024.

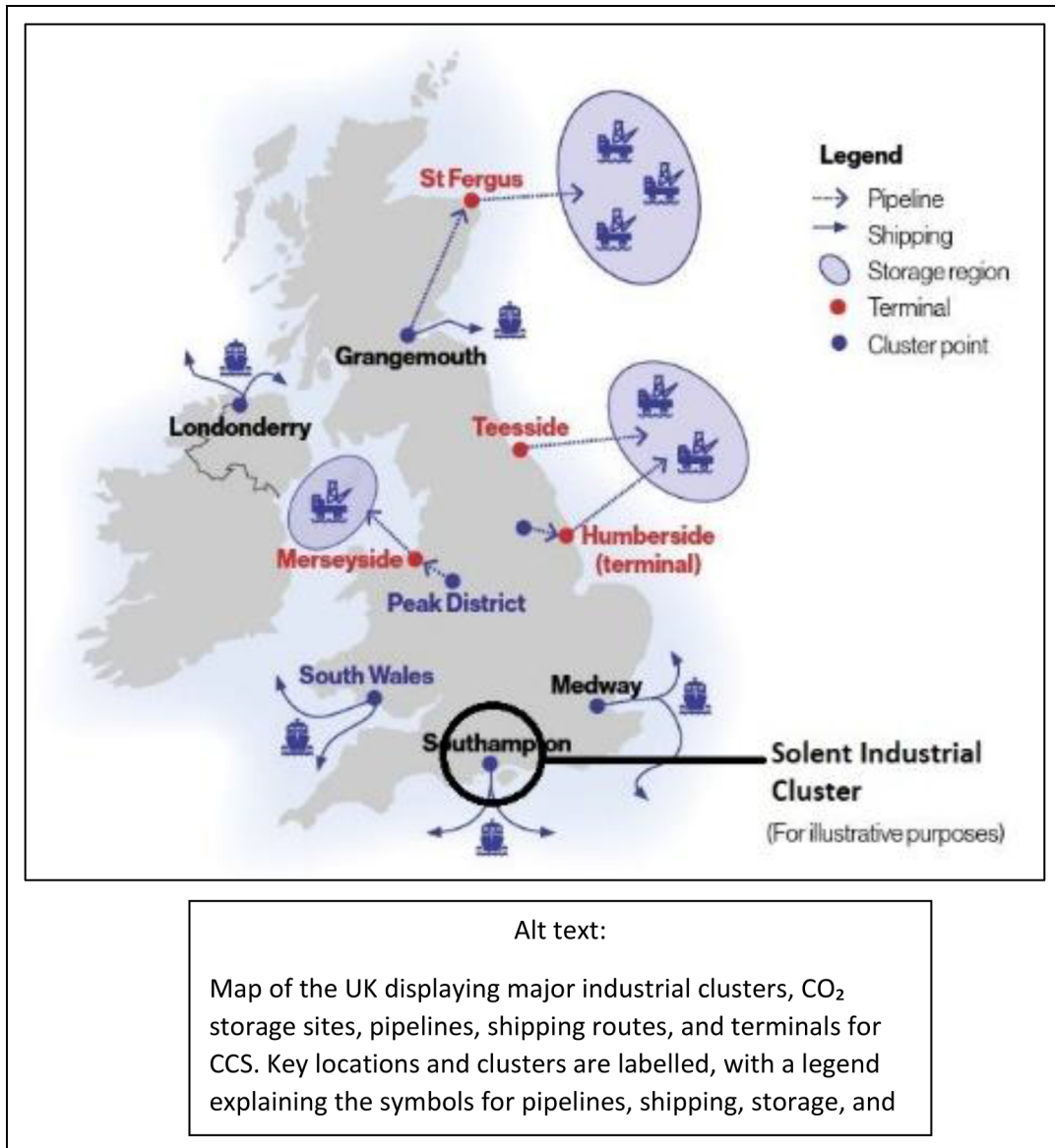


Figure 4. Annotated map illustrating that CO₂ injection points do not always coincide with the geographical location of industrial clusters like the Solent cluster.

legal uncertainty for both regulators and operators. This regulatory fragmentation is inconsistent with HMG's ambitions to safely scale CO₂ shipping as an NPT in support of CCS deployment and risks undermining environmental oversight during a critical phase in the development of the national T&S infrastructure.

To resolve these shortcomings and align the regulatory framework with the UK Government's CCS ambitions, we recommend two targeted amendments to the EPR:

- First, the CCS-specific regime should be expanded to explicitly include additional CCS activities, including CO₂ conditioning, liquefaction, and temporary storage. This would bring relevant installations, including port-based temporary storage facilities, within the scope of the EPR's CCS permitting framework, without relying on the ambiguous regime of 'directly associated activities'. A broadened CCS-specific regime must enable CCS permits to impose a comprehensive suite of environmental safeguards necessary to prevent, detect, and respond to pollution arising from CCS activities, while being tailored to port-specific risks. In particular, permits should include clear requirements for detecting and responding to LCO₂ leakage, ensuring that no pollution source remains unregulated. This targeted approach would ensure consistent regulation across the CCS value chain and prevent confusion arising from CO₂'s variable classification under different EPR provisions.
- Second, CO₂ should be excluded from the EPR's waste management and water discharge provisions to streamline environmental regulation and avoid regulatory overlap. This would prevent conflicting or duplicative requirements for the temporary storage of LCO₂ at ports. Importantly, such an exclusion would not remove environmental protections. Any accidental CO₂ release would still fall under the Environmental Damage (Prevention and Remediation) Regulations 2015⁷⁹ or general health and safety legislation.⁸⁰ While certain fallback regulatory provisions, such as the requirement to notify and obtain a water discharge permit, would no longer apply to CO₂, this is unlikely to result in a practical enforcement gap. CO₂ is not typically managed as a waste matter, and enforcement powers currently available under water and waste permits can be replicated in an expanded CCS permitting framework. As long as the CCS permits include explicit conditions for spill contingency, monitoring, and management of waste streams associated with CO₂ handling, the level of environmental protection will be maintained.

In summary, port-based CO₂ activities are not effectively governed under the EPR's current waste and water discharge regimes. Excluding CO₂ from those provisions, while simultaneously expanding and strengthening the CCS-specific regime, would reduce regulatory uncertainty and ensure coherent, consistent, and robust environmental oversight. This approach is both legally sound and aligns with Government policy direction.

Conclusion

In this paper, we critically examined the regulatory framework governing temporary LCO₂ storage in UK ports within the context of CCS, with a particular focus on the EPR. We began by situating the importance of CCS in the UK's Net-Zero strategy and highlighting the growing significance of shipping and port-based infrastructure for flexible and scalable CO₂ T&S.

⁷⁹ Environmental Damage (Prevention and Remediation) Regulations 2015 (EDR). In contrast to the EPR, the EDR focus on preventing and remedying environmental damage *after* it has occurred or when it is imminent. While the EPR take a proactive, preventive approach by imposing permit conditions and thresholds in advance, the EDR adopt a reactive yet still preventive model. Liability under the EDR is strict and rests with the operator, reinforcing the 'polluter pays' principle. In practice, this means that excluding CO₂ from the EPR's waste management and water discharge provisions would not create a regulatory gap with respect to the prevention or remediation of environmental harm from storage activities. Liability regimes such as the EDR play a complementary role in risk management, and their continued application preserves environmental safeguards while simplifying the regulatory landscape for CCS stakeholders.

⁸⁰ See for example the Control of Substances Hazardous to Health Regulations 2002 which classifies CO₂ as a 'substance hazardous to health'. See also Health and Safety Executive, *Control of Substances Hazardous to Health: The Control of Substances Hazardous to Health Regulations 2002. Approved Code of Practice and Guidance* (6th edn, HSE Books 2013) L5, 9–11 and 14.

Table 1. Summary of recommendations for amending the EPR to regulate temporary LCO₂ storage in support of CCS in the UK.

Recommendation	Description	Intended outcome
Expand the EPR's CCS-specific regime	Explicitly include CO ₂ conditioning, liquefaction, and temporary storage in the EPR's CCS-specific provisions. Remove reliance on 'directly associated activities'.	Ensure port-based storage facilities are clearly within scope. Enable tailored CCS permits with clear environmental safeguards, including LCO ₂ leak detection and response. Promote regulatory clarity and consistency across the CCS value chain.
Exclude CO ₂ from the EPR's waste management and water discharge activities regimes	Amend the EPR to formally exclude CO ₂ intended for CCS from its waste management and water discharge provisions, thereby removing overlapping regulatory requirements.	Streamline regulation of port-based LCO ₂ storage while maintaining environmental protection through strengthened CCS permits and existing legislation.

Using a case study inspired by the LIDP report, we explored the regulation of temporary storage of LCO₂ in ports under the EPR's CCS-specific regime, as well as its provisions on water discharge activities and waste management. Our analysis traced the regulatory journey from the broad legal definitions underpinning the EPR to the practical realities faced by operators and regulators.

We found that, while the EPR offers a robust framework for environmental protection, its current CCS-specific provisions do not fully extend to the regulation of temporary LCO₂ storage associated with shipping. The regulatory gap is most apparent where storage activities in ports are undertaken on a separate site from where CO₂ capture occurs. We then assessed whether this gap can be addressed through applying the EPR's provisions on water discharge and waste management. Our analysis revealed that, although the definition of 'waste' is theoretically broad to include such storage activities, legal uncertainties and practical constraints significantly limit the effectiveness of these provisions in regulating LCO₂ storage in this context.

Throughout the paper, we have highlighted the challenges and ambiguities that arise from this partial regulatory coverage. Our findings underscore the need for greater clarity and coherence in the regulatory treatment of temporary LCO₂ storage in ports to support the safe and effective deployment of CCS. To address these gaps, we made targeted recommendations aimed at enhancing regulatory certainty and ensuring that the EPR framework can accommodate the evolving needs of CCS infrastructure. We summarise these recommendations in Table 1 below.

In doing so, we also contribute to ensuring robust environmental protection as HMG pushes forward with its ambition to unlock a new UK market in cross-border CO₂ T&S, which will include CO₂ shipping.⁸¹ This would enable the provision of geostorage services in the North and Irish Seas to other European countries, positioning the UK as a leader in international CCS cooperation.⁸²

Finally, we believe that the insights and recommendations developed in this study not only support the UK's ambitions but also provide practical guidance for regulators and policymakers in other jurisdictions.

⁸¹ DESNZ, n 12 above.







⁸² The CCSA's Delivery Plan 2035 estimates that the UK could import a further ~20 metric tons of CO₂ per year by 2035 from neighbouring countries. See 'CCUS Delivery Plan 2035' (CCSA, 2022) at <https://www.ccsassociation.org/wp-content/uploads/2022/03/CCSA-CCUS-Delivery-Plan-2035-MASTER-Final.pdf> (last visited 23 June 2025), 5, 49.

Our analysis raises awareness of potential regulatory challenges that may similarly arise as CO₂ shipping becomes an essential component of large-scale decarbonisation efforts.

List of abbreviations

CCS	Carbon capture and storage
CCS Directive	European Union Directive on the Geological Storage of Carbon Dioxide (2009/31/EC)
CCSA	Carbon Capture and Storage Association
CCS-specific regime	Section 6.10, Chapter 6, Part 2, Schedule 1 to the EPR
CLP	European Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures as amended for Great Britain
CO ₂	Carbon Dioxide
DESNZ	HMG's Department for Energy Security & Net Zero
EA	HMG's Environment Agency
EPR	Environmental Permitting (England and Wales) Regulations 2016
GHG	Greenhouse Gas(es)
HMG	His/Her Majesty's Government
HSE	HMG's Health and Safety Executive
IMO	International Maritime Organization
LCO ₂	Liquified Carbon Dioxide
LIDP	Solent Local Industrial Decarbonisation Plan
NPT	Non-pipeline transport
Section 5.3	Section 5.3 of Part 2 of Schedule 1 to the EPR
Section 5.4	Section 5.4 of Part 2 of Schedule 1 to the EPR
Section 5.6	Section 5.6 of Part 2 of Schedule 1 to the EPR
Section 5.6(a)(i)	Section 5.6(a)(i) of Part 2 of Schedule 1
WFD	Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance) [2008] OJ L312/3 (Waste Framework Directive)

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