



Guidance on Plant Design and Hazard Analysis for Onshore and Offshore Carbon Capture Installations and Pipelines

Introduction

Carbon dioxide has thermodynamic properties which affect the choice of materials, plant design and the way hazards need to be considered to safely manage a CCUS plant. Although many of these issues are well understood by the industrial gases sector, they are not ‘business as usual’ for the CCUS industry.

Previous Energy Institute guidance released in 2010 and 2013 provided early direction for CCUS plant design and considerations for the analysis and management of their hazards and became well-used resources within the industry.

With the maturing project landscape, diverse international regulatory frameworks and a decade of operational experience, these documents were updated and restructured into two dedicated, complementary guidance documents published in 2024:

- EI 3553 Hazard analysis for onshore and offshore carbon capture installations and pipelines, and
- EI 3554 Good plant design for onshore and offshore carbon capture installations and pipelines.

The documents aim to educate and equip the growing CCUS industry, in particular developers and operators, with a consolidated understanding of good practice across a majority of the CCUS value chain, CO₂ properties, common design challenges and hazard identification and mitigation approaches.

Scope and objectives

Together, the two guidelines encompass a broad and integrated view of the carbon capture and transport chain (see Figure 1 for scope of work), focusing on the aspects required to design, operate and assess safety across both onshore and offshore installations.

EI 3554 provides detailed information on the fundamental properties of carbon dioxide and explains how these influence plant design, operation and safety. The document outlines the available capture technologies, including carbon capture from post-combustion, pre-combustion, oxy-combustion, chemical looping combustion and fuel cell capture options. Consideration is also given to compressor types and the factors to consider when choosing the most suitable compressor for a particular application. The document also explains the processes available to the designer to condition the carbon dioxide stream to meet the required downstream specification.

The guide further addresses the requirements for both onshore and offshore CO₂ transportation, including for new and repurposed infrastructure. Flow assurance challenges are mentioned such as phase behaviour and impurity effects as well as measurement requirements to transfer and quantify the amount of carbon dioxide transferred during the transportation stage. Beyond transport, the guidance covers CO₂ utilisation options with the greatest potential to reduce CO₂ emissions. The guide also provides a summary of current legislation for CCUS projects, with an emphasis on plant design and operation, and the understanding that legislation is still under development in different jurisdictions.

Outside of scope are carbon dioxide subsea or subsurface storage, shipping, and design and operating information for non-CCUS-related uses of carbon dioxide.

EI 3553 focuses on hazard identification and risk analysis across the CCUS chain. It introduces the general properties of CO₂ and the implications of impurities on its thermos-physical behaviour. Besides outlining potential health effects, the hazards described include those associated with phase change including the potential for low temperatures.



The document summarises current legislation for CCUS projects, with an emphasis on hazard and risk analysis, again pointing out that legislation in various jurisdictions is still evolving.

Building on the process safety management framework, the guide sets out a hazard and risk analysis process applicable to CCUS projects. The guide outlines specific hazards and mitigation options for each part of the CCUS chain, including guidance on release and venting strategies, supported by examples of potential consequences in the event of a release of CO₂.

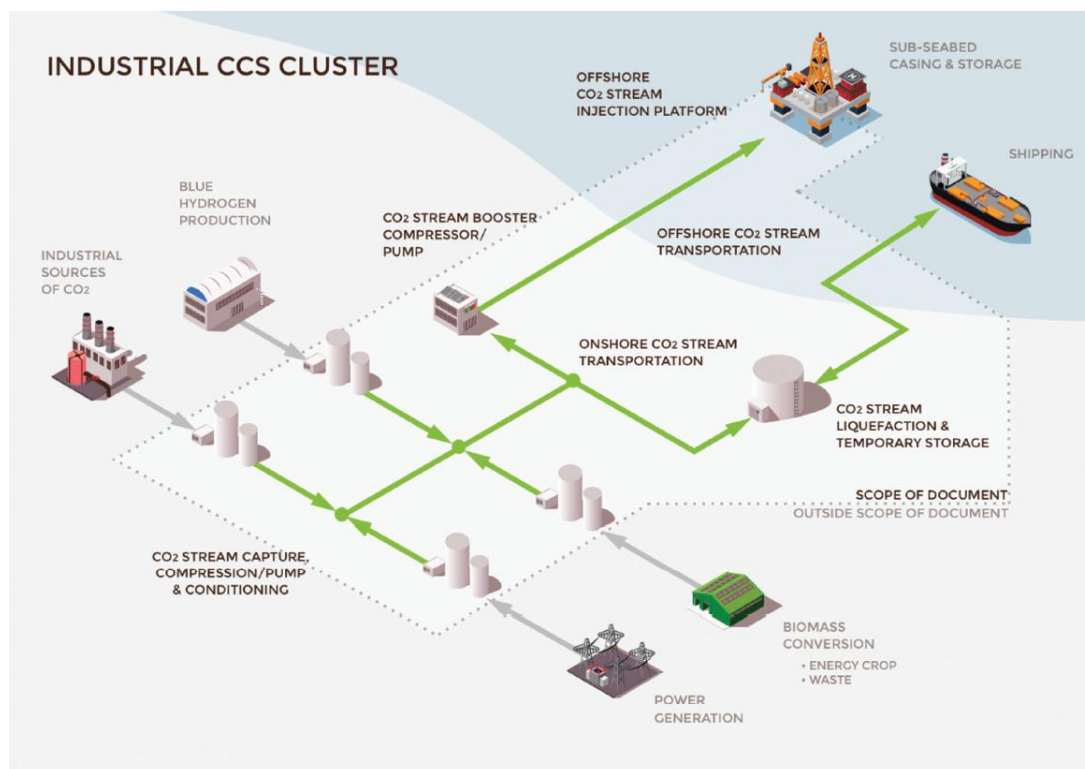


Figure 1: Scope of CCUS chain covered in both guidelines. The documents cover most of the CCUS chain, only omitting CO₂ subsea and subsurface storage and shipping.

Method and/or Theory

Based on the outcomes of an initial cross-industry workshop, it was decided to restructure the three original documents into two comprehensive guidelines. The development of EI 3553 and EI 3554 involved assembling and synthesising the broadest possible base of existing knowledge available to the Energy Institute's CCUS Committee and its dedicated Working Group responsible for updating both documents, consisting of experts from operators, developers, researchers, engineering contractors and regulators. The revision process drew on operational experience, published research and available industry guidance and standards.

Conclusions

The updated EI 3553 and EI 3554 guidelines emphasise several key design and safety principles for CCUS applications. The documents highlight the importance of understanding the overall picture and how system boundaries interface with and impact the design and operation of a CCUS facility. It is important that all parties (developers, operators and regulators, together with the wider contractor and supply chain) independently and jointly ensure that suitable technology, hazard management, risk controls and regulations are developed and implemented to manage the hazards associated with large-



scale CCUS projects. There is a need to align plant design and hazard management with established industry codes of practice and standards, recognising that CO₂ systems often require additional design considerations. Technological standards and regulatory processes need to be embedded from the earliest project stages to ensure that hazard management keeps pace with the scale and ambition of future CCUS infrastructure.

Acknowledgements

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References

EI 3553 Hazard analysis for onshore and offshore carbon capture installations and pipelines, 2nd ed.

EI 3554 Good plant design and operation for onshore and offshore carbon capture installations and pipelines, 2nd ed.