A stochastic programming model for planning CO_2 transport infrastructure with uncertainty

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Abstract

This project develops new algorithms to solve large-scale stochastic optimization problems. The new algorithms focus on the problem of deploying infrastructure to transport CO_2 from industrial sources to sequestration sites with uncertainty. The modelling approach is tested using the illustrative case study of the Humber cluster.

Keywords: CO_2 transport infrastructure construction, multi-stage stochastic programming, scenario tree

1. Introduction

Due to global climate change, it is urgent to reduce emissions of greenhouse gases such as CO_2. As the technology for CO_2 capture is still in its early stages of deployment and has not been widely implemented, the amount of CO_2 that can be effectively captured in the future remains highly uncertain. To optimize the utilization of existing (and future) funding for the transportation of carbon dioxide, it is crucial to develop suitable tools to support decision-makers that are designing a transport network. This involves determining the optimal timing and locations for constructing ships and pipelines.

2. Methodology

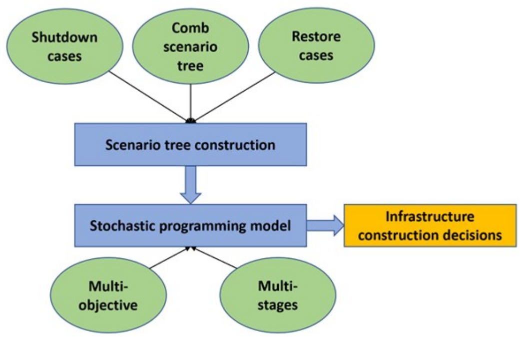

Figure 1: The process to obtain infrastructure construction decisions

The research aims to develop a suitable scenario tree for the CO_2 capture project and apply it in a multi-stage stochastic programming model to provide insights into transportation decision-making at different stages. The process is shown in Figure 1. When constructing the CO_2 capture scenario tree, it is vital to consider potential shutdown situations to account for the risks associated with real-world projects. Factors such as funding shortages or equipment failures may lead to the closure of projects. In addition to shutdown cases, restore cases are also included to reflect the possibility of re-establishing operations in the case of project closures. Furthermore, the incorporation of the comb scenario tree assumes that the CO_2 capture amount of each scenario will eventually converge to a steady state. However, it is necessary to note that the model assumes that no additional infrastructure will be built in the steady state period. Instead, the focus is on understanding the influence for early-stage decisions on the overall system. These assumptions enable the model to capture the long-term dynamics of the project and provide insights into sustainable decision-making strategies. The research also takes into account the multi-objective nature of the problem. One goal is to minimize the cost associated with establishing transport infrastructure and transporting captured CO_2. For the second goal, if the transportation capacity falls short of the total amount of CO_2 that can be captured, a penalty cost is incurred. This approach allows for a balanced analysis of cost reduction and fulfilling transportation demands. As a result, the model incorporates a threshold for determining whether to proceed with infrastructure construction in the first stage. If the penalty cost exceeds the threshold, indicating a significant economic impact of not meeting the transportation requirements, the model will make a first stage decision to build infrastructure.

3. Summary

By considering various cases of scenario trees with their associated probabilities as input, the model offers investors the flexibility to assess different potential outcomes of CO_2 capture development. This assists investors making first-stage decisions based on their expectations and risk appetite. Once a suitable scenario tree is chosen, the model will determine the optimal transportation decisions for both the present and the future assisting in making investment decisions and allocating funding effectively.