OPERATIONAL FLEXIBILITY OF CO_2 TRANSPORT AND STORAGE

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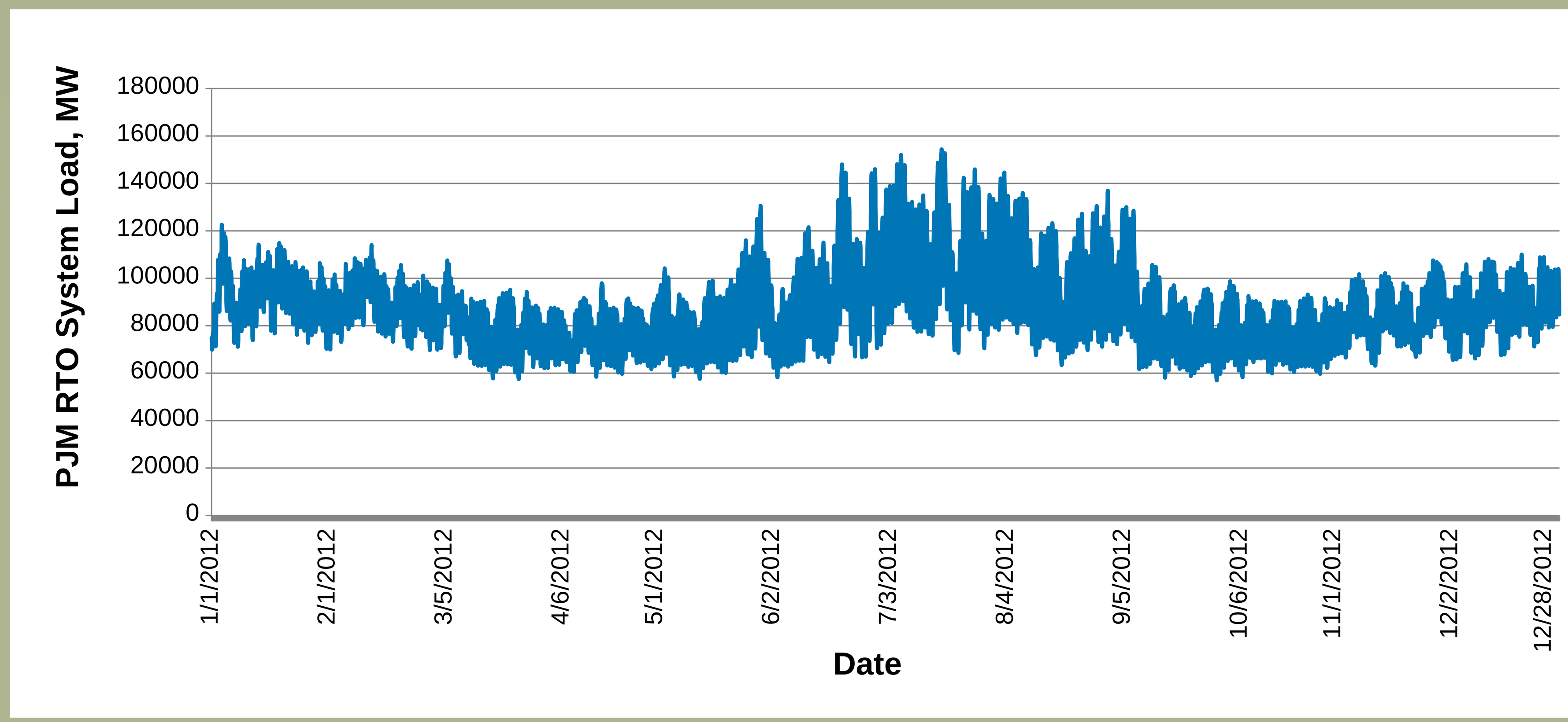
Introduction

Carbon dioxide (CO_2) is produced in large quantities during electricity generation and industrial processes. Each different process produces a CO_2 stream having a different composition. In addition, the CO_2 generation rate can vary substantially for at least some of the processes. For example, generation of CO_2 from electric power plants fluctuates with power demand, which varies both on a short-term (minute-to-minute) and a longer-term (seasonal) basis. The design and operation of the entire CO_2 capture, compression, transport, and storage system must account for these types of variations. The impact on pipeline and storage operation by varying mass flow rate or composition is not fully understood in terms of either operability or infrastructure robustness. It is important that the magnitude of the challenges posed by variation of CO_2 stream flow rate and/or composition be understood so that solutions can be offered to minimize deleterious effects.

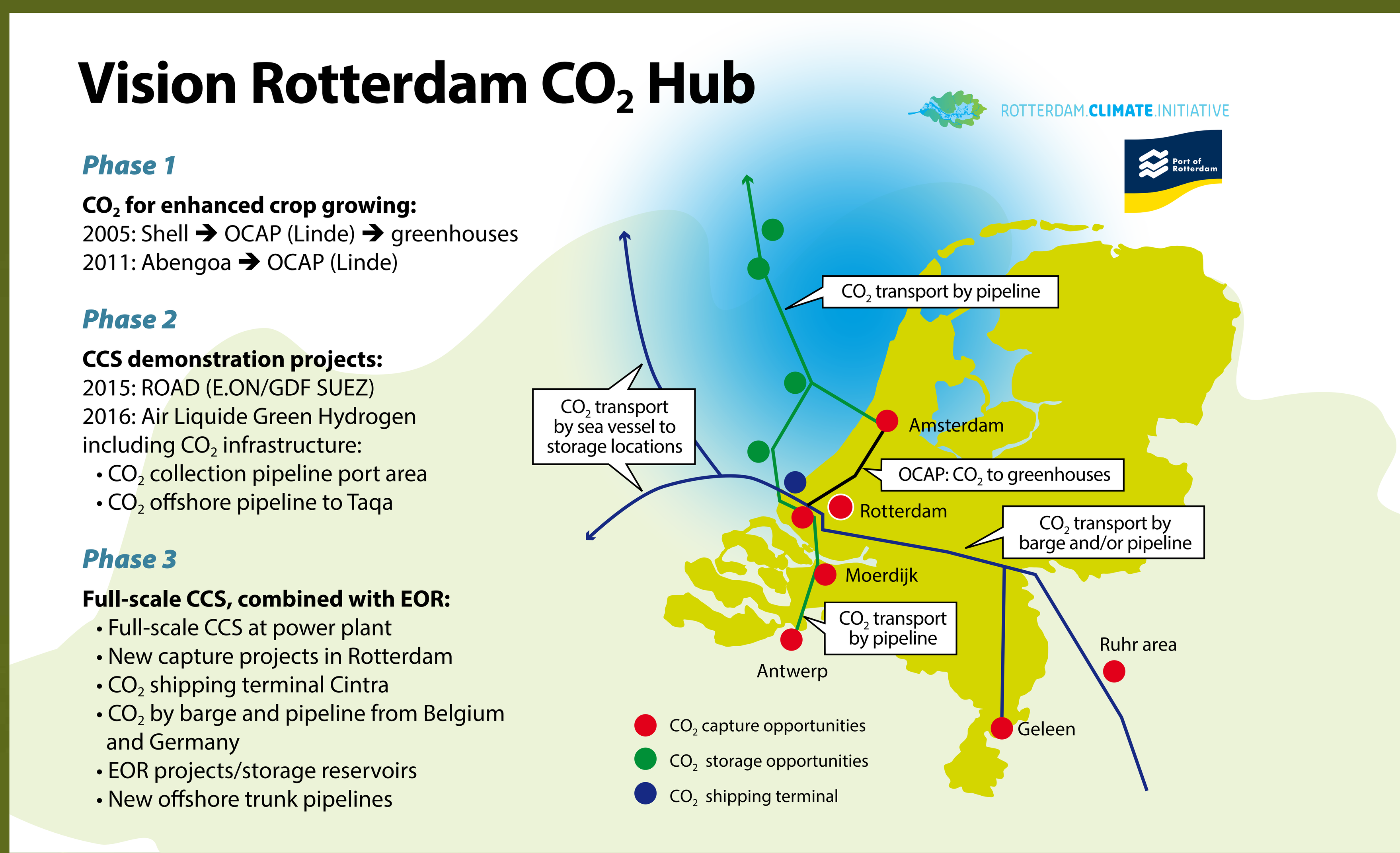
The goal of this study was to ascertain the extent of the technical challenges posed by the transport and storage of CO_2 from emission sources that do not produce a consistent CO_2 stream in terms of composition and/or mass flow rate. A literature search was performed to provide a basis for understanding the various issues associated with the transport and geologic storage of variable and/or intermittent CO_2 streams. Publicly available information was collected on the operational flexibility of existing CO_2 pipelines and geologic storage facilities as well as modeled scenarios. Telephone interviews were conducted with experts in CO_2 pipeline transport, injection, and storage to acquire real-world, anecdotal information that was used to augment information found during the literature searches.

This project began in February 2014 and ended in January 2015.



Variable CO_2 production. Electrical system load is directly related to the emission of CO_2. This chart shows the variation of the system load for the PJM Interconnection Regional Transmission Organization (RTO) in the eastern United States during 2012.

Pipeline network. There are more than 6600 km (4100 mi) of CO_2 pipelines in the United States. Additional pipelines are planned in Canada and the United States but are not shown on this map.



Pipeline hub. Map of the Rotterdam CO_2 hub in the Netherlands. The OCAP CO_2 pipeline carries CO_2 through a 97-km pipeline from a refinery to greenhouses to enhance plant growth.[1]

Issues Studied

Many aspects related to the impact of variable or intermittent CO_2 streams on pipeline and storage operability and robustness were studied during the performance of this project, including:

- The extent of variability of CO_2 produced by different source types.
- Process control strategies; health, safety, and environmental issues; and parameters affecting capital, operating, and maintenance costs of CO_2 pipelines and geologic storage sites.
- Design options for a pipeline network so as to minimize the effects of source variation.
- The effects of CO_2 stream composition on injection/subsurface behavior and phase change during transient pipeline conditions.

CO_2 pipeline. Denbury's Green Pipeline was designed to transport both natural and anthropogenic CO_2 and is routed near several potential industrial CO_2 sources.[2]

Findings

- Impurities in the CO_2 stream change the physical and transport properties of CO_2 as well as the stream's hydraulics, which may make it difficult to maintain single-phase flow within the CO_2 pipeline. The presence of impurities also makes it more difficult to model the conditions needed for safe depressurization and operation at transient conditions.
- Pipeline control strategy depends upon the ability to control the volumes received from the sources and delivered to the storage sites. Temporary storage and pipeline networks and hubs can be useful for controlling the flow in a pipeline or set of pipelines to minimize compositional and/or mass flow rate variations:
  - Temporary storage can consist of fabricated vessels, temporary geologic storage, or pipeline packing, where the pipeline operating pressure is increased to "pack" more CO_2 into the pipeline.
  - Networks can consist of a dedicated pipeline linking a single source to a single geologic sink or various combinations of multiple sources and multiple geologic sinks.
  - Hubs are the point on a pipeline at which multiple smaller pipelines either join or leave the main pipeline. The smaller pipelines bring CO_2 from various sources or distribute it to various sinks.
- Intermittent flow potentially can cause hydrate formation and salt precipitation in the reservoir/downhole environment.
- Techniques, procedures, and protocols developed by the CO_2 enhanced oil recovery industry to minimize the effects of variable or intermittent CO_2 flow on both pipelines and well and reservoir operations are likely applicable to other carbon capture and storage situations.

CO_2 injection. The Sleipner A CO_2 injection platform is on the right.[3]

Acknowledgments

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