

# LNG LIQUEFACTION PROCESS SELECTION: ALTERNATIVE REFRIGERANTS TO REDUCE FOOTPRINT AND COST

Russell H. Oelfke  
*Robert D. Denton*  
Michael R. Miller

ExxonMobil Upstream Research Company

## 1 ABSTRACT

This paper describes recent work at ExxonMobil Upstream Research Company to identify novel refrigerants and processes for production of liquefied natural gas (LNG) in large-scale floating and onshore LNG facilities. The goal of the research was to reduce the footprint and cost of baseload LNG plants through the use of non-flammable or reduced flammability refrigerants.

Process results are presented and discussed for two novel liquefaction cycles: a mixed refrigerant process and a cascade process. The performance aspects of each process are discussed, and tradeoffs in process complexity and equipment flexibility are considered.

## 2 BACKGROUND

### 2.1 Incentives

The design of an efficient refrigeration system is of paramount importance for effective and economic LNG production. Several commercially available refrigeration cycles are currently in use at baseload LNG plants. Most of these cycles share a common feature: the use of flammable hydrocarbon refrigerants, such as methane, ethane or ethylene, propane, isobutane, isopentane, and their mixtures (often with nitrogen as well).

Facility space is significantly more costly for floating LNG (FLNG) plants than for onshore plants. The use of flammable refrigerants and the requirement for appropriate spacing and other measures to prevent adverse consequences in the event of refrigerant release increases the capital costs of FLNG projects. Requirements for safe refrigerant makeup, handling, storage, and import on to floating vessels also increase FLNG costs relative to onshore plants.

Replacing hydrocarbon refrigerants with non-flammable, or reduced flammability, refrigerants offers the potential for reducing the capital costs of FLNG projects. There are also potential cost reductions for onshore LNG plants, as requirements for "buffer zone" land surrounding and within plant sites may be reduced. These economic benefits can only be realized if the liquefaction cycles using the alternate refrigerants have comparable thermal efficiency and equipment requirements relative to the conventional liquefaction processes.

### 2.2 Alternative Refrigerants

In considering alternative refrigerants for baseload LNG projects, we evaluated several classes of refrigerants, including hydrofluorocarbons (HFCs), noble gases, and fluorocarbon refrigerants with reduced greenhouse warming potential.

A list of selected conventional and alternative refrigerant candidates appears in Table 1. The table uses the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) "R-code" numbering system, which numerically identifies refrigerants based on their chemical structure.<sup>1</sup> The R-codes will be used to refer to specific refrigerants in the balance of this paper. Table 1 also lists the chemical name, chemical formula, molecular weight, normal boiling point, melting point, critical temperature, safety group, and greenhouse warming potential for each of the refrigerants.

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