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## Energy Efficient and Sustainable Refrigeration Systems

**Course Number:** ME-02-701

**PDH:** 6

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After the course has been purchased, review the technical material and then complete the quiz at your convenience.

A Certificate of Completion is available once you pass the exam (70% or greater).

If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).

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### Module 1. Introduction

#### Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary drivers for adopting low-GWP and natural refrigerant technologies in commercial facilities.
- **Evaluate** the applicability of course concepts to various facility scales based on building square footage.

*Executive Summary:* This section establishes the foundation for selecting and designing energy-efficient refrigeration systems. Given that refrigeration often accounts for more than half of a supermarket's energy consumption, shifting toward low-GWP and natural refrigerants is critical for environmental stewardship and regulatory compliance.

#### Design Fundamentals

**Refrigeration systems** represent the most significant energy demand in supermarket-type buildings. As a Professional Engineer, understanding the intersection of energy efficiency and environmental impact is essential due to the following factors:

- **Energy Consumption:** Systems typically account for **more than half** of a building's total energy use.
- **Environmental Impact:** Conventional **hydrofluorocarbon (HFC)** refrigerants possess high global warming potential and contribute to climate change when leaked.
- **Market Trends:** There is a distinct shift toward **environmental stewardship** and proactive management of **compliance requirements** in the United States.

#### Course Application and Scope

This module facilitates informed decision-making regarding low-GWP and natural refrigerant technologies to maximize value for building owners.

- **Target Facility Size:** While developed for traditional supermarkets ranging from **40,000–60,000 square feet**, the engineering principles apply to both smaller and larger commercial facilities.
- **Methodology:** Content focuses on **transparent methods** for calculating system performance at design conditions and throughout the year using hourly energy analysis.
- **Technical Depth:** This material provides insights into **compliance, design applications, and economic evaluations**.

💡 **Design Tip:** Use this course as a strategic framework. It is intended to equip designers with the necessary ideas and tools to assist in the design process rather than providing a "turn-key" complete design or exact energy savings calculations.



### Checkpoint Quiz

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- 1. A supermarket owner is planning a 75,000 square foot facility. According to the course scope, how should the designer approach this project?**
- a) Disregard the course as it only applies to facilities up to 60,000 square feet.
  - b) Apply the concepts, as they are relevant to various facility sizes with commercial refrigeration.
  - c) Only use the sections regarding energy consumption, as design applications will not scale.
  - d) Use the course only if the facility uses HFC refrigerants.

**Answer:** (b). Concepts apply to smaller and larger facilities beyond the 40,000-60,000 square foot baseline.

- 2. Which of the following best describes the primary objective of the transparent methods provided in this course?**
- a) To provide a 100% complete and final construction design.
  - b) To offer precise, guaranteed energy savings for any natural refrigerant application.
  - c) To enable designers to calculate actual system performance at design conditions and via hourly analysis.
  - d) To replace the need for professional engineering judgment during the design process.

**Answer:** (c). The methods focus on advancements in understanding through performance calculations and hourly energy analysis.



## Module 2. Technologies and Trends

### Learning Objectives

By the end of this section, you will be able to:

- **Trace** the historical progression from natural to synthetic refrigerants and the subsequent return to low-GWP alternatives.
- **Identify** the regulatory frameworks, such as the Montreal Protocol and the Clean Air Act, that mandate the phase-out of ozone-depleting substances.
- **Evaluate** the environmental impact of refrigeration systems by applying the Total Equivalent Warming Impact (TEWI) metric.

*Executive Summary:* The evolution of commercial refrigeration has been driven by a constant balance between safety and environmental stewardship. While synthetic HFCs solved the ozone depletion crisis, their high global warming potential has necessitated a shift toward a holistic design approach measured by Total Equivalent Warming Impact (TEWI), which accounts for both direct leaks and indirect energy consumption.

### History

The earliest commercial refrigeration systems utilized **natural refrigerants**, including **ammonia (NH<sub>3</sub>)**, **propane**, and **carbon dioxide (CO<sub>2</sub>)**. However, concerns regarding high working pressures, toxicity, and flammability led manufacturers to develop synthetic chemical alternatives known as "**safety refrigerants**".

- **Synthetic Development:** These refrigerants primarily consisted of **chlorofluorocarbons (CFCs)**.
- **Safety Benefits:** CFCs offered lower operating pressures and reduced flammability/toxicity.
- **Environmental Impact:** By the 1970s, scientists discovered that these chemicals were significantly depleting the Earth's **ozone layer**.

### Regulation

Regulatory mandates have since become the primary driver for technology changes in the refrigeration industry.

- **Montreal Protocol (1989):** Developed by the United Nations Environment Programme to regulate ozone-depleting substances.
- **Clean Air Act of 1990:** Directed the U.S. Environmental Protection Agency (EPA) to implement a phase-out plan for ozone-depleting chemicals.
- **Chlorine Content:** Any refrigerant containing chlorine atoms, such as **R12 (CFC)** and **R22 (HCFC)**, was slated for phase-out due to its ozone-depletion potential.



### Initial Response

The industry's first response to the Clean Air Act was to replace CFCs and HCFCs with **hydrofluorocarbon (HFC)** refrigerants, which do not contain chlorine.

- **Equipment Innovation:** Manufacturers introduced **low-charge refrigeration systems**, including secondary glycol systems and distributed direct expansion (DX) systems.

### Mixed Results

While HFC refrigerants effectively eliminated ozone depletion, their implementation introduced two new critical challenges:

- **Global Warming:** These chemical refrigerants have a direct impact on the energy balance of the atmosphere when leaked.
- **Energy Efficiency:** Some HFC systems are less energy-efficient than their predecessors, leading to **indirect negative impacts** through emissions from power generation.

### New Metric to Account for Direct and Indirect Global Warming Factors

To address these challenges, engineers utilize the **Total Equivalent Warming Impact (TEWI)** to quantify a system's holistic global warming impact. TEWI accounts for two specific sources:

- **Direct GHG Releases:** These are caused by inadvertent leaks at fittings or releases during maintenance.
- **Indirect GHG Emissions:** These stem from the power generation required to operate the system.

**Standard GWP Reference:** Refrigerants are compared to the 100-year climate impact of **CO<sub>2</sub>**, which has a GWP of 1. For example, **R-404a** has a GWP of 3700, meaning 1 lb of leaked R-404a is equivalent to 3700 lb of CO<sub>2</sub>.



**Calculation Note:** The average indirect emission factor in the United States used for TEWI calculations is **1.23 lb of CO<sub>2</sub> per kilowatt-hour** of electricity consumed.



### Checkpoint Quiz

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**1. Why did the refrigeration industry transition from natural refrigerants to synthetic CFCs in the mid-20th century?**

- a) To protect the ozone layer.
- b) Due to concerns over the toxicity and high working pressures of natural refrigerants.
- c) To comply with the Clean Air Act.
- d) Because CFCs have a lower Global Warming Potential (GWP).

**Answer:** (b). Safety concerns regarding toxicity and pressure were the primary drivers.

**2. Which of the following is considered an "indirect" environmental impact in the TEWI metric?**

- a) Refrigerant leaks from a poorly sealed fitting.
- b) Emissions released during a routine maintenance service.
- c) CO<sub>2</sub> emissions produced by the power plant supplying electricity to the refrigeration system.
- d) The direct warming effect of HFCs on the atmosphere's energy balance.

**Answer:** (c). Indirect impacts refer to emissions from the energy generation required for system operation.

**3. If a designer is comparing two systems, what does a higher TEWI value indicate?**

- a) The system is safer for technicians but more expensive.
- b) The system has a higher combined impact on global warming from both leaks and energy use.
- c) The system is more effective at protecting the ozone layer.
- d) The system uses only natural refrigerants.

**Answer:** (b). TEWI is a holistic quantification of total global warming impact.



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