



Opportunities for Decarbonization in Industrial Refrigeration

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What is Net Zero?



Net Zero

- The term **net zero** refers to the target of reducing the greenhouse gas emissions that cause global warming to zero, by balancing the amount released into the atmosphere from sources with the amount removed and stored by carbon sinks
- In accordance with the 2015 Paris Agreement, the world must reach net-zero GHG emissions early in the second half of the present century. That will require the transformation of economies and societies alike
- Many countries and corporations are setting their aspirations to achieve net zero goals by 2050

What is Decarbonization?



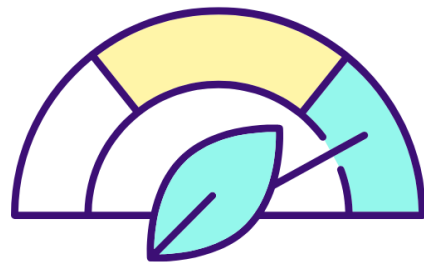
Decarbonization

Decarbonizing existing buildings means getting them completely off fossil fuels. Without burning fossil fuels onsite, most buildings will need to provide space and water heating using electricity instead— typically with heat pumps.

Electrification: Refers to using technologies such as vehicles or heat pumps that operate with electricity instead of burning fossil fuels such as oil, gas, and coal. Electricity generated through clean resources such as wind and solar power is considered a decarbonization strategy.

U.S. Green Building Council supports beneficial electrification, specifically with deep **energy efficiency** and peak management, as a core strategy for building **decarbonization**.

What is Energy Efficiency?



Energy Efficiency

Energy efficiency is the use of less energy to perform the same task or produce the same result. Energy-efficient homes and buildings use less energy to heat, cool, and run appliances and electronics, and energy-efficient manufacturing facilities use less energy to produce goods.

Energy efficiency is one of the easiest and most cost-effective ways to combat climate change, reduce energy costs for consumers, and improve the competitiveness of U.S. businesses.

Energy efficiency is also a vital component in **achieving net-zero emissions of carbon dioxide through decarbonization.**

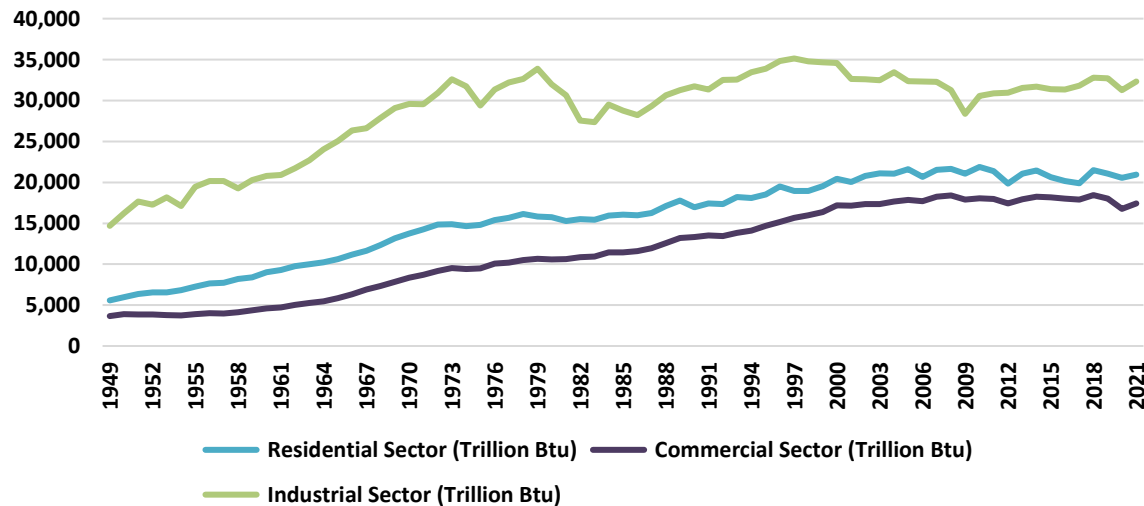
The Office of Energy Efficiency and Renewable Energy (EERE)

<https://www.energy.gov/eere/office-energy-efficiency-renewable-energy>

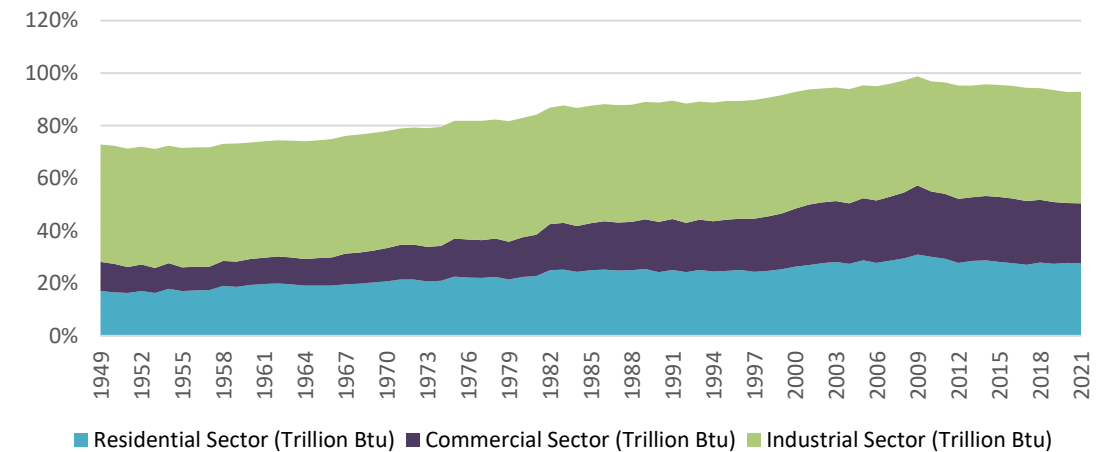
Energy Consumption Comparison Residential, Commercial, and Industrial Sectors



Table 2.1a Energy Consumption: Residential, Commercial, and Industrial Sectors Title



Energy Consumed by Residential, Commercial and Industrial Sectors - Participation%



- Residential Sector: 23% in 1949 and 30% in 2021
- Commercial Sector: 15% in 1949 and 25% in 2021
- Industry Sector: 61% in 1949 and 45% in 2021

The industry is the bigger energy consumer sector in the USA.

Energy Consumption in the Industrial Sector



Industrial sector: An energy-consuming sector that consists of all facilities and equipment used for producing, processing, or assembling goods. The industrial sector encompasses the following types of activity manufacturing (NAICS codes 31-33); agriculture, forestry, fishing, and hunting (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); and construction (NAICS code 23).

Overall energy use in this sector is largely for process **heat and cooling** and powering machinery, with lesser amounts used for facility heating, air conditioning, and lighting. Fossil fuels are also used as raw material inputs to manufactured products.

Energy Use in the Industrial Sector



The United States is a highly industrialized country. In 2021, the industrial sector accounted for 35% of total U.S. end-use energy consumption and 33% of total U.S. energy consumption.

Industry uses many energy sources

The U.S. industrial sector uses a variety of energy sources including:

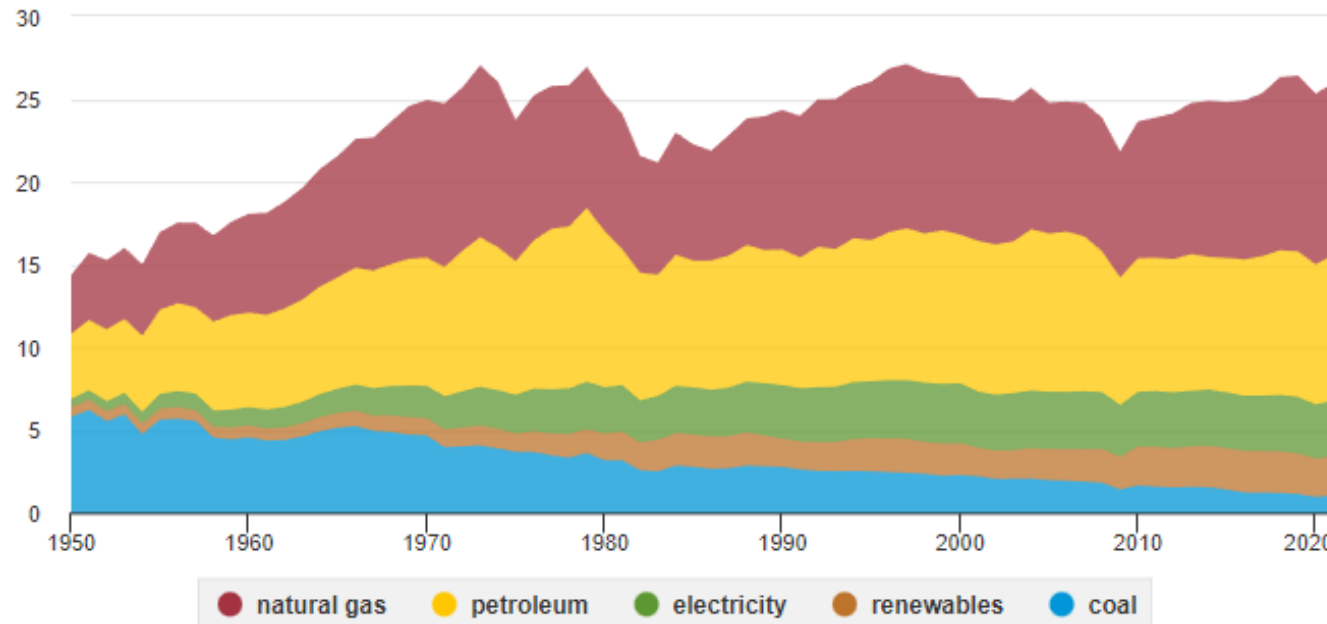
- Natural gas
- Petroleum, such as distillate and residual fuel oils and hydrocarbon gas liquids (HGLs)
- Electricity
- Renewable sources, main biomass such as pulping liquids (called *black liquor*) and other residues from papermaking and residues from agriculture, forestry, and lumber milling
- Coal and coal coke

Energy Use by Source



U.S. industrial sector energy use by source, 1950-2021

quadrillion British thermal units

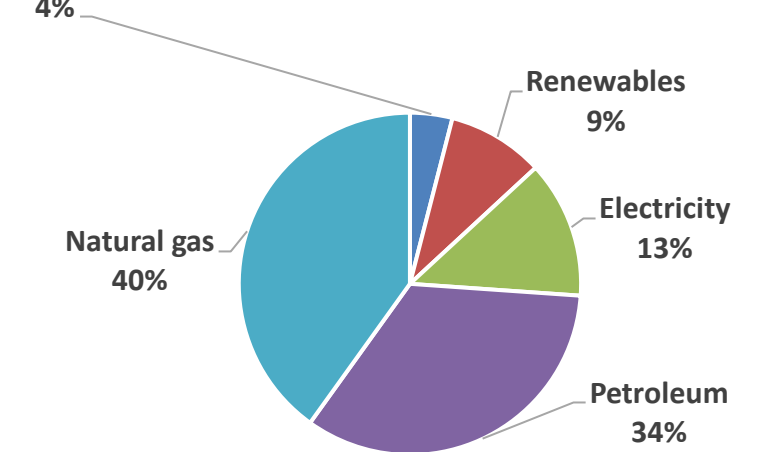


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 2.4, April 2022, preliminary data for 2021

Note: Includes energy sources used as feedstocks in manufacturing products. Electricity is retail sales of electricity to the sector and excludes electric system energy losses associated with the retail sales.



Energy Sources for industry in 2021



Highly dependent on the use of fossil fuels – Natural Gas (40%) and Petroleum (34%).

Energy Use by Type of Industry



Within the industrial sector, manufacturing accounts for the largest share of annual industrial energy consumption, generally followed by mining, construction, and agriculture. Mining includes the extraction of minerals, and nonmineral products such as stone and gravel, coal, oil, and natural gas. Agriculture includes farming, fishing, and forestry. Manufacturing is the physical, mechanical, or chemical transformation of materials or substances into new products. The U.S. Energy Information,

Administration (EIA) makes projections for energy consumption by these four major industrial activities in the Annual Energy Outlook, which include the types and amounts of energy used by the type of industry and manufacturers.

Types of Energy



Most industries purchase electricity from electric utilities or independent power producers. In addition, some industrial facilities also generate electricity for their own use using fuels that they purchase and/or the residues from their industrial processes. Some manufacturers produce electricity with solar photovoltaic systems located on their properties. Some industrial facilities sell some of the electricity that they generate.

Industry uses fossil fuels and renewable energy sources for:

- **Heat in industrial processes and space heating in buildings**
- **Boiler fuel to generate steam or hot water for process heating and generating electricity**
- Feedstocks (raw materials) to make products such as plastics and chemicals

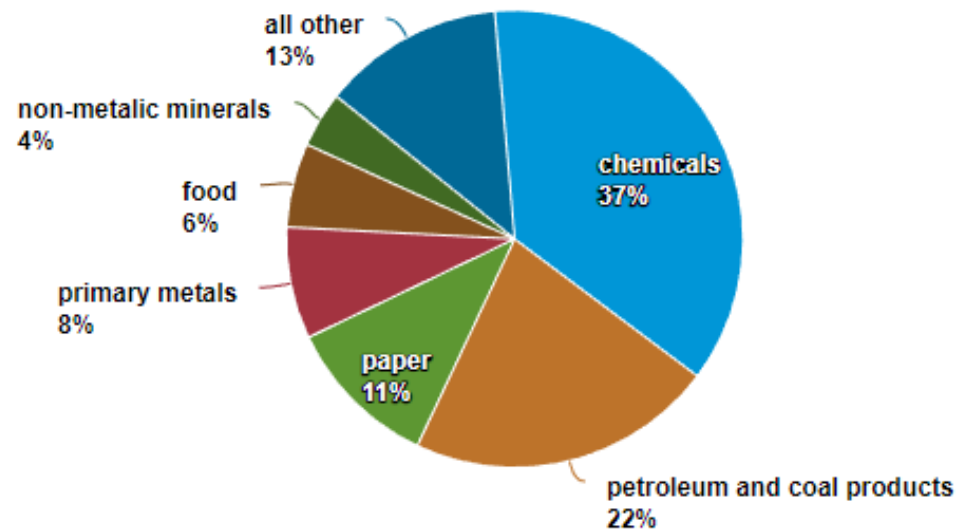
The industrial sector uses **electricity for operating industrial motors** and machinery, lights, computers, and office equipment, and equipment for facility heating, cooling, and ventilation.

Energy Consumption by Type of Subsectors



U.S. manufacturing energy consumption by major types of manufacturers, 2018

total = 19.44 quadrillion British thermal units



Data source: U.S. Energy Information Administration, *Manufacturing Energy Consumption Survey 2018*, Table 1.2, February 2021



Note: Includes electricity purchases and energy sources used as feedstocks for making products. Sum of shares may not equal 100% because of independent rounding.

Manufacturing energy consumption by subsector and type of energy in 2018 (trillion British thermal units)

Subsector	Fuel	Nonfuel	Total
Chemicals	2,815	4,326	7,141
Petroleum and coal products	3,342	903	4,245
Paper	2,488	3	2,491
Primary metals	1,734	307	2,041
Food	1,511		1,511
Nonmetallic minerals	1,161		1,161
All others	247	599	846
Total	13,298	6,138	19,436

Manufacturing Energy Consumption by Subsector



Manufacturing energy consumption includes fuel and nonfuel sources

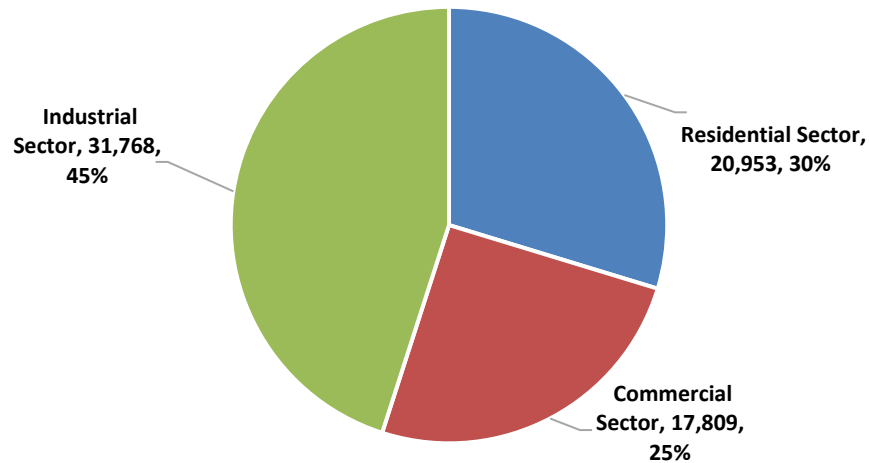
Manufacturers consume two general types of energy sources—*fuel* and *nonfuel*. Fuel consumption is the use of combustible energy sources to produce heat and/or to generate electricity (which, by manufacturers, is mostly for their own use), and the use of electricity to operate equipment and associated manufacturing facilities.

Nonfuel sources are feedstocks (raw materials) that are used to make products. According to MECS 2018, fuel use accounted for about 68% and nonfuel sources/feedstocks accounted for about 32% of the total first use of energy by U.S. manufacturers in 2018.

Participation and Energy Sources for Industrial Sector

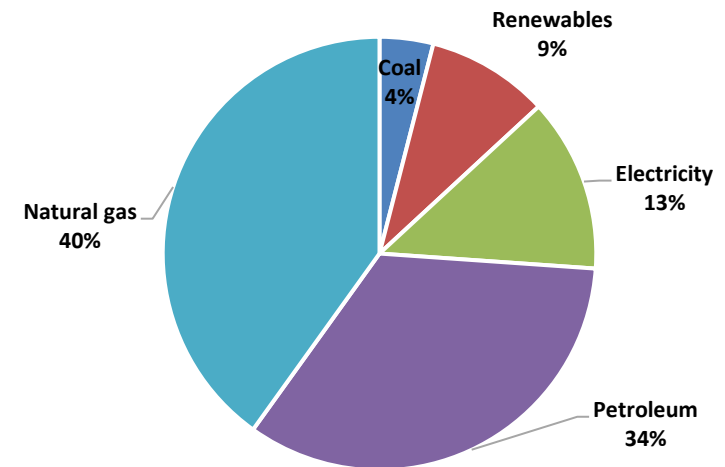


Average Annual Consumption by Sector
2001 to 2021 (Trillion Btu)



On average, the Industrial Sector represents 45% of Total Energy Consumption in the USA, in the last 20 years (excluding Transportation).

Energy Sources for industry in 2021

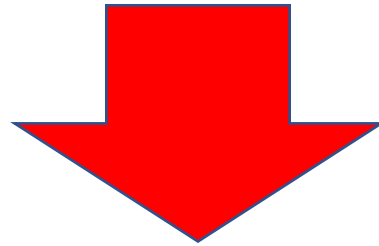


Electricity represents only 13% of energy sources in the Industry Sector

Opportunities for Decarbonization



Natural gas, petroleum, and coal represent 79% of other energy sources in the Industry Sector



Around 56,000 Trillion BTU per year

Opportunities for Decarbonization



U.S. Green Building Council: Chapter 8 – Energy & Atmosphere

Primary goals:

- Reducing energy demand
- Increasing energy efficiency
- Replacing fossil fuels with renewable energy
- Eliminating the use of harmful refrigerants
- Monitoring ongoing performance

Goal 1: Reducing Energy Demand



Strategies to Reduce Energy Demand

1. Reduce building footprint: reduce energy demand and construction costs
2. Incorporate passive solar design for heating and passive ventilation for cooling
3. Create a high-performance building envelope
4. Establish design and energy goals
5. Participate in a demand response program
 - a) **Demand-side management (DSM)** programs consist of the planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage.

Goal 2: Increasing Energy Efficiency



Strategies to Increase Energy Efficiency:

1. Install high-performance refrigeration systems, which typically cost more than less efficient systems. Utilize life-cycle costing to identify cost payback during a 20 years period
2. Implement normalized energy cost indicators, such as kWh per pound of product, or US\$ per pound of product
3. Analyze operation conditions
4. Establish a predictive maintenance program

*Considering energy efficiency, improvements after system start-up is suboptimal. **The best time to consider energy efficiency is ALL THE TIME.***

Industrial Refrigeration Energy Efficiency Guidebook
Industrial Refrigeration Consortium - IRC

Goal 3: Replacing Fossil Fuels with Renewable Energy



Strategies to Utilize Renewable Energy:

1. Install onsite renewable energy systems
2. Purchase off-site renewable energy

Goal 4: Eliminating the Use of Harmful Refrigerants



Strategies to Eliminate Harmful Refrigerants

1. The goal is to eliminate the use of CFCs entirely and use more ozone-friendly refrigerants
2. Natural refrigerants such as ammonia (NH_3) and carbon dioxide (CO_2), are widely used in industrial refrigeration systems
3. Natural refrigerants are completed ozone-friendly options

Goal 5: Monitoring Ongoing Performance



Strategies to Monitoring Ongoing Performance






1. Install a fully automated refrigeration system to adjust capacity based on the production thermal load
2. Monitoring of energy consumption
3. Create a set of Key Performance Indicators (KPI) to monitor ongoing performance
4. Establish benchmarks among different sites for performance improvement
5. Look for additional energy efficiency measures, based on measurement data

Florida End-use Energy Consumption 2020




2.743 Trillion BTU (including Transportation)

By Source

-  Coal – 0.2%
-  Natural Gas – 8.2%
-  Petroleum – 56.3%
-  Renewable Energy – 5.2%
-  Electricity – 30.1%

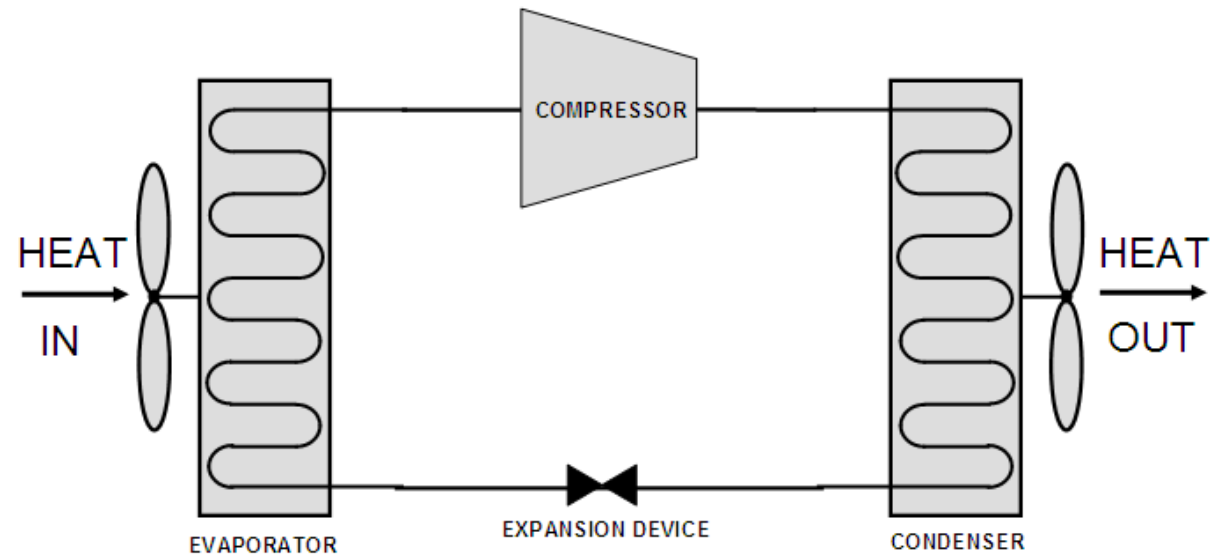
By Type

-  Residential: 523.3 Trillion BTU – 39%
-  Commercial: 426.9 Trillion BTU – 32%
-  Industry: 375.7 T BTU – 28%

Refrigeration Cycle

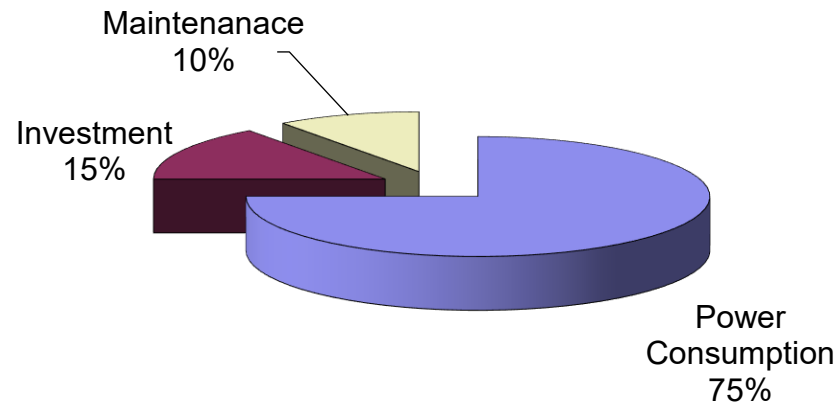
The refrigeration system transfers heat from one environment to another. The way heat is efficiently transferred, depends on several factors:

- Cooling system design
- Equipment efficiency
- Control and automation system
- Operation and maintenance

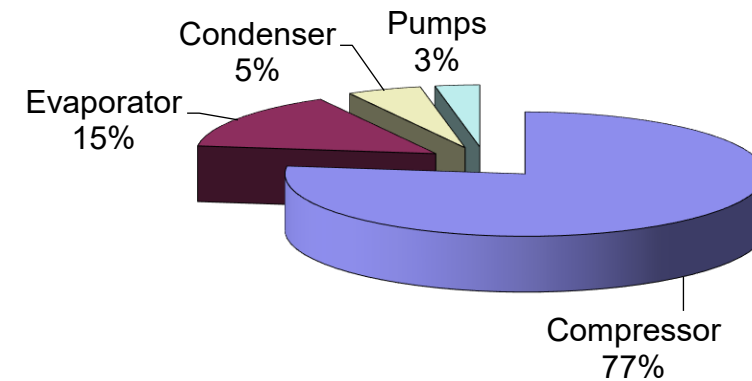


Impact of Electricity on Industrial Refrigeration

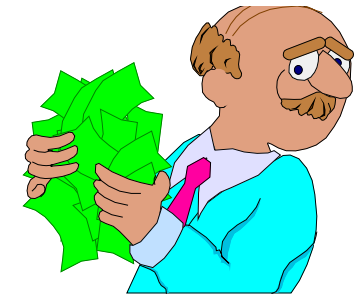
Total Cost of Ownership - 20 Years



Estimated Consumption by Equipment



The Engine Room consumes approximately 70% of the electricity in the food processing industry.



Situation in Florida



- The Industry Sector has the lower energy consumption in Florida when compared with other sectors.
- According to the Florida Public Service Commission (FEECA) report from 2021, the Industry Sector represents only **8.1% of total Electric Consumption in the state.**
- Nevertheless, on the path to net zero, Florida has opportunities for decarbonization and energy efficiency improvements in the Industry Sector
- One of the most important areas of opportunity is the industrial heating process, by analyzing the use of heat pumps to replace boilers that use fossil fuels.

Independent Consulting Services



- Bennu is positioning itself to be a service provider to Florida Food & Beverage industry, by offering the following activities:
 - Evaluation of different industrial refrigeration system designs, looking for energy efficiency during the system life cycle
 - Total cost of ownership analysis of different systems options
 - Analysis of current industrial refrigeration systems
 - Evaluation of heat pump utilization in the heating process, to reduce carbon emissions

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