Medical Devices Market Characterization Study

Final Report

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Executive Summary

This report presents findings from a market study of medical device energy efficiency. The specific devices studied in this report include magnetic resonance imaging (MRI) machines, computed tomography (CT) scanners, X-ray machines, positron emission tomography (PET) scanners, infusion pumps, dialysis machines, ventilators, room air cleaners (air purifiers and ionizers), continuous positive airway pressure (CPAP) machines, and heating pads. The project team quantified the potential for energy savings and identified device types with opportunities for higher efficiencies through review of existing research, applicable regulations, codes and standards, and operational manuals as well as conversations and interviews with individuals representing national laboratories and ENERGY STAR, healthcare professionals working within radiology departments, and manufacturers of medical devices. This report identifies mechanisms and recommended efforts for achieving higher energy efficiency and energy savings in the California market.

Summary of Market Evaluation Findings

- Regulations, Standards, and Codes
    - Policymakers have traditionally exempted medical equipment from energy-efficiency regulations.
    - Residential air cleaners are the only studied medical devices in this market characterization that have published codes and standards governing the energy consumption and performance of the devices.
    - EPA has been working on an ENERGY STAR specification for medical imaging equipment for over a decade. The most recent draft was released in April 2024 and focuses solely on MRI machines during non-operational modes.
    - The European Coordination Committee of the Radiological, Electromedical, and Healthcare IT Industry (COCIR) has created a self-regulatory initiative for medical imaging equipment (MIE) in response to a directive that allowed the Energy Commission to place eco-design requirements on any group of products that utilize energy.
- Existing Research on Medical Device Energy Consumption and Use
    - Research on medical devices in healthcare facilities has primarily focused on medical imaging equipment.
    - Medical device energy consumption is highly variable: there are different operational modes, run hours, quantity of patients treated, and types of operational use.
    - Devices that are left in ready to scan or operational modes when low power modes are available use significantly more energy.
    - The primary mechanism for achieving energy efficiency and savings is through power management of devices.
- Insight and Feedback from Stakeholders
    - Energy management and radiology professionals are looking for guidance on how to reduce energy consumption of plug loads, including medical devices. They typically look to ENERGY STAR.

- Pressure needs to come from end users to push device manufacturers to improve energy efficiency and power management capabilities of devices.
- A live database of power management instructions would be very valuable for procurement and sustainability teams.

Summary of Energy Consumption and Savings Potential Findings

- Medical Devices used in Hospitals and Healthcare Facilities
  - While infusion pumps have a comparatively small (166 kWh) energy consumption per device, the sheer number of estimated devices in California leads to a total estimated energy consumption (328.3 GWh) nearly twice that of MRI machines (141.8 GWh). While VEIC did not uncover any existing work on energy-efficiency improvements or power management strategies for these devices, incremental improvement in the efficiency of these devices could lead to significant energy savings in the state of California.
  - The total estimated energy consumption of CT scanners (85.1 GWh) was less than that of MRI machines (141.8 GWh), however, the overall energy savings associated with improved power management strategies of CT scanners (26.3–40.8 GWh) has greater potential for energy savings than that of MRI machines (30.9 GWh).
  - Dialysis machines have a significantly smaller estimated energy consumption (2.4 GWh) in comparison to the other devices studied, and previous studies indicate these machines already spend most of their time in low power or off modes, leading to negligible energy savings potential, if any.
  - Overall savings estimates of medical devices from prior research do not account for the effectiveness of technician training, education, and policy around switching MIE machines into low power modes or the market penetration of equipment with capability to automatically set back into low power mode.
- Medical Devices used in Residential or Home-Health Settings
  - Of the devices studied in this report, the market and technical characterization of air cleaners is by far the most mature.
  - VEIC found limited information to characterize the energy consumption and savings potential for CPAP machines, ventilators, heating pads, dialysis machines, and infusion pumps.
  - While information to estimate the energy consumption of CPAPs exists, little to no information was found on existing or planned savings measures for these device types. While information on the average energy consumption per device of infusion pumps and dialysis machines in residential settings may be similar to those studied in hospital and healthcare facility settings, VEIC did not find existing information on the California market size.
  - Limited research on heating pads exists, including the use of custom heating pads as personal comfort systems to reduce heating and cooling loads in buildings. The market is fragmented with many manufacturers. The use of heating pads for heat therapy is variable and uncertain. Furthermore, heating pads are explicitly

excluded from the qualifying medical devices of a few California Investor-Owned Utilities' (IOUs) Medical Baseline Allowance (MBA) programs.

Summary of Recommendations

- The primary mechanism for achieving greater energy efficiency and savings is through power management of medical devices.
- Further research and data collection is needed to quantify and characterize the energy consumption and savings potential of PET scanners, ventilators, infusion pumps, and dialysis machines. Additionally, further research, including metering of MIE, is needed to capture load profiles of different facility types and use cases within the US to strengthen energy consumption and savings estimates.
- Metering medical equipment in hospitals poses challenges due to patient privacy and disturbance concerns. A metering guideline should be developed to reduce barriers for teams to collect data on energy consumption and load profiles.
- Programs should use the forthcoming ENERGY STAR specification as a guideline for identifying devices eligible for efficiency incentives and end users should advocate for the expansion of the ENERGY STAR specification to all medical imaging equipment.
- A live database of power management instructions should be built out and maintained for use by radiology professionals and healthcare sustainability teams.
- Manufacturers should be required to report energy consumption characteristics of their devices.

Abbreviations and Acronyms

Acronym	Meaning
ACS	US Census Bureau American Community Survey
AHRQ	Agency for Healthcare Research and Quality
AHS	American Housing Survey
ASHRAE	The American Society of Heating, Refrigerating, and Air Conditioning Engineers
CADR	Clean Air Delivery Rate
CalTF	California Technical Forum
CBECS	Commercial Building Energy Consumption Survey
CDC	US Census Data and Center for Disease Control
CEC	California Energy Commission
CFR	Code of Federal Regulations
CHARME	Collaborative for Healthcare Action to Reduce MedTech Emissions
COCIR	European Coordination Committee of the Radiological, Electromedical, and Healthcare IT Industry
CPAP	Continuous Positive Airway Pressure
CPUC	California Public Utilities Commission
CT	Computed Tomography Scanner
DOE	US Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FDA	Federal Food and Drug Administration
HCAI	California Department of Health Care Access and Information

Acronym	Meaning
HHS	US Department of Health and Human Services
HUD	US Department of Housing and Urban Development
IEF	Integrated Energy Factor
IOUs	California Investor-Owned Utilities
LBNL	Lawerence Berkley National Laboratory
LPCH	Lucille Salter Packard Children's Hospital
MBA	Medical Baseline Allowance
MedTech	Medical Technology
MEP	Mechanical, Electrical, Plumbing
MIE	Medical Imaging Equipment
MRI	Magnetic Resonance Imaging
NREL	National Renewable Energy Laboratory
OECD	Organization for Economic Co-Operation and Development
PAP	Positive Airway Pressure
PET	Positron Emission Tomography Scanner
RECS	Residential Energy Consumption Survey
SEM	Strategic Energy Management
SHC	Stanford Hospital and Clinics
SUMC	Stanford University Medical Center
T	Tesla
TSD	Technical Support Document
US	United States
UV	Ultraviolet

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Introduction

Millions of medical devices are used in the state of California every day. While critical for maintaining life-sustaining functions, supporting health, and enhancing comfort, these electrically powered devices also consume a substantial amount of energy.

Management of medical device energy efficiency in healthcare settings is not well understood or implemented. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) is currently funding a study on "Reporting the Energy Use and Heat Gain from Imaging Equipment." However, the scope is focused on improving information for cooling load estimation by heating, ventilation, and air conditioning (HVAC) design engineers and not the management of heat gain or efficiency of the equipment. While there is a forthcoming ENERGY STAR® specification for medical imaging equipment, it will address only a specific subtype of energy consuming medical devices in healthcare facilities.

The influence of hospital regulations and accreditation requirements on the energy use of medical devices may be significant but has been unclear in the context of energy management barriers and opportunities. Healthcare facilities in California are subject to regulation by the California Department of Health Care Access and Information (HCAI) and accreditation by the Joint Commission. Additionally, an operational culture of "always ready" is common in hospitals. This is associated with regulatory requirements and can be influential on energy consumption. This project investigates the regulatory barriers and opportunities for operating medical devices in lower (non-active) power modes.

Power demand of residential medical devices varies significantly across devices of the same type. Some of these devices also have digital control capabilities that are amenable to energy management through active, standby, and off modes of operation. Further research is needed to quantify the potential for energy management through procurement of higher-efficiency models, as well as automated controls and monitoring. This project gathers stakeholder input on available data for device quantities, load profiles, and controls to characterize statewide consumption and saving potential.

The efficient operation of residential and healthcare facility medical devices is complicated by the diversity of equipment types, makes and models, and use cases. A barrier to operating medical devices efficiently is the accessibility of operating instructions for the setup and use of lower power modes. Device users lack the time to research the power modes available and how to access them, as priorities are focused on providing patient care. To reduce the barrier of information accessibility, this project investigates the information needed for users and operators of devices to improve power management. A prototype reference table of such power management instructions for major categories of medical devices will be designed for direct access by the public and for use as guidance in identification and quantification of low to no cost energy-efficiency measures in utility supported energy audits, retro-commissioning studies, and strategic energy management (SEM) programs.

Medical device manufacturers play a direct role in the provision of higher efficiency devices. New devices are developed and sold to meet the operational requirements of end users. Some residential

medical devices have remote monitoring capabilities for tracking device effectiveness and usage, which may also enable better energy management. This project investigates both the energy management capabilities in development by manufacturers and the energy management needs of healthcare personnel and patients, to inform efforts by California hospitals, regulators, insurance companies, and utility programs to obtain the best available technology and practices in the marketplace.

Background

The healthcare sector consumes approximately eight percent of the total electrical consumption in the United States (US) from commercial buildings (EIA 2021). Lighting, ventilation, and cooling combined consume approximately 77 percent of the electrical use in hospitals. The next largest load falls within miscellaneous loads, at approximately 12 percent (Evergreen Economics and SBW Consulting 2015). One study found miscellaneous electrical loads within healthcare facilities in the US represent approximately 30 percent of electric energy consumption (Black, Lanzisera, et al. 2012), with an estimated 5 percent of total site energy use attributed to medical imaging equipment (MIE), a subset of medical devices included in this study (DOE 2023).

California's Investor-Owned Utilities (IOUs) have Medical Baseline Allowance (MBA) programs that assist residents who are dependent on power for their home medical devices. The devices covered by these programs typically include medical devices needed to sustain life. Three of the devices included in this market characterization study are also included in the MBA programs: infusion pumps, ventilators, and dialysis machines. The programs specifically exclude heating pads. Air ionizers and air purifiers are not on the qualifying products list or are specifically listed as excluded. These devices (heating pads, air ionizers and air purifiers) do not typically aid in sustaining life and are often used to improve comfort, health, and/or indoor environmental quality, which is likely why they are not included. MBA programs do not span the state because they are only present in the three largest IOUs (Pacific Gas and Electric 2024, Southern California Edison 2023, San Diego Gas and Electric Company 2023). These programs aim to reduce the energy burden, but not energy use, associated with medical equipment.

Decarbonization Efforts in the Healthcare Sector

Efforts to improve sustainability within the healthcare sector have been ongoing for over two decades. In 2001, Health Care Without Harm partnered with the American Hospitals Association, the US Environmental Protection Agency (EPA), and the American Nurses Association to create the Hospitals for a Healthy Environment program. In 2008, the Hospitals for a Healthy Environment program was reorganized and renamed Practice Greenhealth, now a leading membership-based organization committed to advancing sustainable practices within the healthcare community. Practice Greenhealth developed a Sustainable Procurement Guide to provide step-by-step guidance, tools, and resources to healthcare organizations around sustainable purchasing. The procurement guide is accessible through Practice Greenhealth membership. The project team was not able to secure a copy of the guide to review whether it includes guidance on operational energy efficiency of devices included in this market study. Additionally, Practice Greenhealth hosts the annual CleanMed conference in collaboration with Health Care Without Harm. While the 2024 conference agenda

included a number of sessions on sustainable procurement of medical devices and supplies, there was only one session specifically focused on the energy savings opportunities of electrically powered medical devices, more specifically magnetic resonance imaging (MRI) systems.

While there have been organizations focused on sustainability within the healthcare sector for over two decades, there has been a significant emphasis on decarbonization efforts within the sector in the last few years. In 2021, representatives from the National Academy of Medicine, the US Department of Health and Human Services (HHS), and nationwide healthcare companies announced the launch of the Action Collaborative on Decarbonizing the US Health Sector (Dzau, et al. 2021). The call to action published in the New England Journal of Medicine discusses the significant threat climate change poses to human health and the healthcare sector's significant contributions to greenhouse gas emissions and climate change (Dzau, et al. 2021). While the Action Collaborative advocates for sustainable procurement of medical devices, it does not specifically address the operational energy consumption of medical imaging equipment or other prolific medical devices. In 2022, the HHS Agency for Healthcare Research and Quality (AHRQ) published a report outlining measures healthcare organizations can take to reduce scope 1, 2, and 3 carbon emissions. Medical devices and supplies are addressed within the report; however, the report focuses heavily on reducing waste and carbon emissions associated with single-use medical devices, rather than the operational energy associated with electrically powered medical devices (Sampath, et al. 2022).

In 2023, Kaiser Permanente and Health Care Without Harm released a white paper and roadmap for health systems and medical technology (MedTech) suppliers to decarbonize the healthcare sector. The roadmap identifies four categories or opportunities for collective action, including renewable energy, product utilization, product innovation, and transportation. In 2024, the Sustainable Purchasing Leadership Council launched a partner initiative with Kaiser Permanente: the Collaborative for Healthcare Action to Reduce MedTech Emissions (CHARME). The CHARME initiative hopes to convene stakeholders within health systems including medical device and equipment suppliers and distributors to implement the actions laid out in the white paper. While CHARME could be leveraged to advance operational energy efficiency of medical devices and equipment, the product innovation and product utilization categories focus heavily on decarbonizing supply chain and waste programs and do not mention or specifically address the operational energy consumption of such devices (Kaiser Permanente, Health Care without Harm and Accenture 2023).

Overview of Medical Devices

This study aims to characterize the markets for and identify opportunities and barriers to greater energy efficiency of ten unique medical device types. The list of devices included in this study is not exhaustive; it contains a selection of commonly used, electrically powered health devices found in both healthcare and residential settings. The list was further refined based on the available information found during project planning and aims to capture a range of criticality, from life-sustaining to improved comfort and pain reduction. Each device is broadly categorized as residential or commercial based on the setting in which the device is used. Generally, residential devices are electrically powered devices found at home or outside of healthcare facilities and are used to reduce environmental pollutants, improve overall health, and/or sustain life. The residential devices included in this study are room air purifiers and ionizers, positive airway pressure (PAP) machines, ventilators, heating pads, infusion pumps, and dialysis machines. Generally, commercial medical

devices include devices with significant plug loads, like MIE, and electrically powered devices prolific in hospitals and healthcare facilities. The commercial medical devices included in this study are MRI machines, computed tomography (CT) scanners, electromagnetic radiation (X-ray) machines, position emission tomography (PET) scanners, infusion pumps, and dialysis machines. Of the ten unique devices studied, infusion pumps and dialysis machines are used in both residential and commercial healthcare settings. Table 1 includes a brief description of these medical devices.

Table 1: Overview of Medical Devices

Device Type	Definition/Description
MRI Machines	MRI machines are used to obtain highly refined images of the body's interior. These devices employ magnets that polarize and excite hydrogen nuclei in water molecules within tissues and create two-dimensional images (EPA 2024).
CT Scanners	CT scanners create a computer-generated three-dimensional image from a large series of two-dimensional X-ray images taken around a single axis of rotation. CT scans use X-rays to produce precise cross-sectional images of anatomical structures and spaces within objects (EPA 2024). They can provide more detail than a traditional X-ray (N. NIBIB 2022).
X-ray Machines	X-ray machines produce images when a small amount of ionizing radiation passes through the body. The ability of X-rays to penetrate tissues and bones varies according to the tissue's composition and mass. Examples of devices using general radiography include a cyberknife, fluoroscope, and linear accelerator (EPA 2024). X-ray machines can be used for diagnostics, as well as therapy (N. NIBIB 2022). This market characterization focused on diagnostic X-ray machines.
PET Scanners	A PET scanner is a type of nuclear imaging technology, in which a patient consumes short-lived isotopes that emit radiation that is measured, commonly with the use of a gamma camera to produces three-dimensional images (EPA 2024). These scanners can be combined with CT and MRI machines for improved diagnostic imaging (Mayo Clinic 2023).
Infusion Pumps	Infusion pumps deliver fluids into the body in a controlled manner. There are many different types of infusion pumps; they can be designed for stationary use (at a patient's bedside) or portable use (wearable), and they can be electrically or mechanically powered (FDA 2017).
Dialysis Machines	A hemodialysis machine filters blood through a dialyzer, removing waste, salts, and fluids. Dialysis treatment may take place in a healthcare facility such as a hospital or dialysis center, or at a patient's home with the appropriate equipment and training (Mayo Clinic 2023).
Ventilators	A ventilator is a mechanical machine that moves air in and out of your lungs. Ventilators can be used in hospitals or at home (N. H. NHLBI 2022).

Device Type	Definition/Description
Room Air Cleaners (air purifiers and ionizers)	Room air cleaners are electric appliances that remove particulate matter from the air by moving the air through a filter or electrostatic plates. Some air cleaners also include an ion generator in addition to the fan or filter. These devices can be moved between rooms (EPA, ENERGY STAR Program Requirements for Room Air Cleaners 2022).
Continuous Positive Airway Pressure (CPAP) machines	A CPAP ventilator uses pressurized air to keep breathing passages open while a patient sleeps (N. NHLBI 2022).
Heating Pads	A heating pad is an electrical device intended for medical purposes that provides dry heat therapy for body surfaces. It can maintain an elevated temperature during use (FDA 2023).

Source: Project Team

Objectives

The primary objectives of this market characterization study are to:

- Quantify potential scale of energy savings achievable through energy management of medical devices.
- Identify opportunities for procuring more efficient equipment and for operating equipment more efficiently. Procuring includes purchasing for commercial users and purchasing or renting for residential users.
- Identify gaps in knowledge and barriers to implementation for more efficient medical devices.
- Develop a reference table of power management instructions for major categories of medical devices to reduce the barrier of information accessibility for the public and utility efficiency program administrators of prescriptive incentives, custom commercial and industrial incentives e.g., hospital energy audits and hospital retro-commissioning studies, and SEM programs.
- Provide recommendations for further research necessary to achieve the potential scale of energy savings from medical devices and recommendations for incorporating medical device efficiency into utility programs for energy efficiency, including prescriptive incentives, retro-commissioning programs, and SEM programs.

Methodology and Approach

To understand the current state of the market, as well as ongoing and future efforts to improve the energy efficiency of medical devices, the project team conducted a literature review, engaged with several stakeholders, and estimated the energy consumption and savings potential of devices included in this study from available secondary data sources. The following sections describe the

methodology and approach to each of these. Additionally, the project team developed a reference table with example records of power management instructions, presented in Appendix A. Insights from the literature reviewed and conversations with stakeholders informed the design of the reference table.

Literature Review

The project team conducted a review of existing literature to characterize the market for residential and commercial medical devices and equipment. The team reviewed existing research, applicable regulations, codes and standards, and operational and technical manuals to characterize the market and determine power consumption, operational modes, and typical use of devices. This information was combined to provide insights and recommendations on the market today.

The project team reviewed research papers, fact sheets, program specifications, and presentations from national organizations and universities. Most of the research reviewed was from the last five years, but insights were also gathered from research published in the last 20 years. Current regulations surrounding the use and manufacturing requirements of medical devices were also examined. Of the literature reviewed, priority was placed on research addressing power consumption during different operational modes of the medical equipment. Research in the state of California was preferred over research in other areas of the country and world. However, since this area of research has only emerged in recent years, many sources came from prior research conducted throughout the country and within Europe.

The collated sources were prioritized towards industry-relevant material, with a focus on energy impacts; market and technical evaluations; baseline and potential studies; and innovative medical equipment intervention strategy white papers. Research directly connected to the California Public Utilities Commission (CPUC), California Energy Commission (CEC), California Technical Forum (CalTF), and the California IOUs was also prioritized.

The findings from the secondary literature review were synthesized to identify gaps and topics for focus of the primary research activities. The literature review also identified gaps in the standards, test procedures, specifications, and field evaluations and recommendations for future research. Limitations include the lack of research or study on certain medical devices that need more rigorous research to understand operational power consumption, typical usage patterns, and energy savings opportunities in future studies.

Stakeholder Engagement

The project team conducted outreach and a series of stakeholder interviews to comprehensively understand the opportunities for and barriers to greater medical device energy efficiency, as well as the medical device market. The team spoke with individuals representing national laboratories and ENERGY STAR, as well as healthcare professionals working within radiology, facility, and sustainability departments. Stakeholders were asked a series of open-ended questions regarding device procurement, configuration, operation and maintenance, federal and state regulations for relevant devices, specification development, and opportunities and barriers to reducing energy consumption of medical devices. Table 2 lists those contacted and interviewed.

Table 2: Summary of Stakeholder Engagement

Stakeholder	Purpose and Status of Engagement
National Renewable Energy Laboratory (NREL) Plug and Process Load Team	Interviewed for expert input on the potential for energy savings from medical devices in general and medical imaging equipment, with a focus on addressing known barriers to energy management.
US EPA ENERGY STAR	Interviewed for insights on the future of efficiency specifications, reporting, and standards for medical devices, to best complement the efforts underway at ENERGY STAR.
Healthcare Facility/Energy Management Professionals	Interviewed to understand ongoing efforts and informational needs of personnel promoting energy efficiency at healthcare facilities.
Engineering Consultants Specializing in Healthcare	Interviewed for awareness of leading efforts to understand and manage the energy consumption of medical devices in a healthcare setting.
Manufacturers of Medical Devices	Interviewed to understand the methods by which medical device purchasers and users can reduce energy consumption.
California Department of Health Care Access and Information	Contacted to identify barriers and opportunities for implementing energy management in the purchase and operation of medical devices.
California Health Advocates	Contacted to understand the needs of low-income households and how energy efficiency programs can best serve those needs.
Energy Efficiency Program Administrators	Contacted for input on existing program alignment with medical device efficiency measures.
Radiology Professionals	Interviewed to understand the operational and informational needs of personnel to manage the efficiency of medical devices.
Academic Researchers	Interviewed to further understand ongoing research efforts to characterize and quantify the energy consumption and energy implications of medical devices.

Source: Project Team

Quantifying Energy Consumption and Savings Potential

The methodology for quantifying energy consumption and device savings varied depending on the sector, medical device, and available information. To inform this quantitative analysis, the following data was prioritized and used:

- General information on equipment utilization profiles and operating parameters.
- Device rated power demand and electrical load.
- Power curtailment and energy-efficient intervention strategies, including energy-efficient equipment options.
- Market characterization statistics such as equipment distribution, saturation, and efficient equipment penetration.

The energy use for several of the medical devices studied in this report is poorly characterized in the literature reviewed due to insufficient and lack of quality information. Detailed energy savings approaches, as a result, are also not well assessed qualitatively or quantitatively.

Information was lacking on some medical devices for a variety of reasons. Some devices had a relatively low power load and didn't necessarily warrant further investigation from researchers, such as infusion pumps. Other equipment's functionality and reliability far outweighed the potential for energy savings. Ventilators are an example where manufacturers and end user focus has traditionally been on the reliable function of the machine over its electrical demand. Manufacturers have been slow to adopt energy-efficiency practices at the risk of sacrificing quality care from their equipment. This has limited the available research for energy-efficiency options or strategies for some medical devices. In other situations, energy saving intervention strategies have been slow to adopt or limited by the "necessary to sustaining life" nature of these devices.

Time-series data on equipment operation was another difficult component to characterize for medical devices. Load profile data is necessary to quantify energy use and savings potential as it is a significant indicator of time of use and operational parameters. However, the variability in use patterns, especially in commercial healthcare facilities, differs widely and is correlated with the medical service. For example, equipment used in an intensive care unit will differ significantly compared to equipment used in a general radiology office setting.

Another reason for the scarcity of energy use information of these medical devices is the lack of codes and standards. Medical equipment has traditionally been excluded from energy codes and standards regulations. The only equipment type studied in this report that has federal appliance standards in place is air purifiers. These devices have a robust energy-efficiency platform with an ENERGY STAR specification and are offered broadly as a prescriptive solution within utility demand side management portfolios.

Little to no evaluation or research exists detailing and quantifying the energy savings potential of the medical devices studied in this report. Where VEIC was able to estimate savings potential, it resulted in the collation of several pieces of literature, most of which were standalone white papers. In some cases, VEIC relied on case studies that provided spot measurements or one-off energy mitigation solutions for the medical devices studied.

The traditional databases used to analyze and characterize key components in a market assessment contained limited information on medical devices. The following publicly available datasets and tools were reviewed as part of this analysis:

- Energy Information Administration (EIA) Commercial Building Energy Consumption Survey (CBECS) and Residential Energy Consumption Survey (RECS)[1]
- NREL ComStock and ResStock[2]
- US Census Bureau American Community Survey (ACS)[3] and US Department of Housing and Urban Development (HUD) American Housing Survey (AHS)[4]

After review of these databases, CBECS is the only dataset that contained information on commercial-grade medical imaging equipment. The other databases provided little to no information on equipment saturation or energy use characteristics of medical devices.

As a result, to quantify the market of medical devices in California, databases related to healthcare were scrutinized as they provided information on healthcare facility inventories, diagnostic examinations, and inpatient and outpatient claim information, all of which helped piece together market assessments of medical devices in California.

In this instance, the Organization for Economic Co-Operation and Development (OECD) Data Explorer[5] provided useful information, at a national level, for medical devices. In scenarios where market penetration, saturation, and equipment stock are available at the national and not the state level, the project team extrapolated the data to encapsulate California based on normalizing variables such as the number of hospital beds and other factors as detailed in the table below. Additionally, when information or data was not available on a national level, the project team relied on equipment density data reported by the European Coordination Committee of the Radiological, Electromedical, and Healthcare IT Industry (COCIR) in their Medical Imaging Equipment Age Profile report (COCIR 2021).

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[1] This survey is conducted every four or five years by the EIA in coordination with the US Department of Energy. These datasets provide detailed information on household and commercial building energy characteristics and energy use.

[2] NREL ComStock and ResStock was developed in support from the US Department of Energy and offer real-time data visualization of an immense range of market factors and information. Through a combination of multiple public and private data sources, statistical sampling, sub-hourly building simulations, and high-performance computing, NREL ResStock and ComStock datasets provide granularity on modeling diverse housing and building stock and distributional impacts of building technologies across different communities.

[3] This survey is conducted annually and includes a nationally representative survey that provides demographic information on the US population, including a limited set of energy use characteristics of households.

[4] This survey is conducted biannually and includes a nationally representative sample and collects detailed information on the size, composition, and quality of the nation's housing stock, including physical condition of homes, energy use characteristics, and information on housing subsidies.

[5] OECD is an international organization that shapes policies to foster prosperity, equality, and opportunity. Working with sovereign nations, they establish evidence-based international standards, finding solutions to a range of social, economic, and environmental challenges.

Table 3: Equipment Stock Estimate Scaling Market Factors

Scaling /Normalizing Factor	Value	Source
California Commercial Health Care Building Stock Floor Area (thousand square feet)	480,002	California Commercial End Use Survey
Number of Hospitals in California	335	American Hospital Directory
Number of Staffed Hospital Beds in California	74,324	American Hospital Directory
California Population (people)	38,965,193	2022 US Census Data
US Population (people)	334,914,895	2022 US Census Data
Electricity-Dependent Persons Residing at Home in US	685,482	US Census Data and Center for Disease Control (CDC)
CT Scanner Density (CT scanners per one million inhabitants)	42.63	OECD
MRI Density (MRIs per one million inhabitants)	37.99	OECD
X-ray Density (X-rays per one million inhabitants)	30	COCIR
PET Scanner Density (PET scanners per one million inhabitants)	6.7	OECD

Findings

Findings from the review of existing research, regulations and standards, operational and technical manuals; stakeholder engagement activities; and quantification of energy consumption and savings protentional in the state of California are synthesized and presented in the following sections.

Market Evaluation

To characterize the market for medical devices, the project team reviewed relevant federal and state codes and regulations, energy-efficiency standards, literature from previous research studies, and operational and technical manuals. Additionally, the team engaged with several stakeholders to further understand the opportunities and barriers to greater energy efficiency of medical devices. The initial results from this work are presented in the sections below.

Regulations, Standards, and Codes

Policymakers have traditionally exempted medical equipment from energy-efficiency regulations. Code-required minimum energy performance standards were perceived to potentially impede the equipment's ability to function properly, a serious detriment to health and safety. As part of the California Code of Regulations, Title 20 Appliance Efficiency Regulations specifically exempts external power supplies for medical devices that require Federal Food and Drug Administration (FDA) listing and approval. This language mirrors what is published in the Department of Energy's (DOE) Code of Federal Regulations (CFR), a codification of appliance and equipment standards, rulemakings, and notices.

ENERGY-EFFICIENCY STANDARDS FOR MEDICAL DEVICES

Residential air cleaners are the only studied medical devices in this market characterization that have published codes and standards governing their energy consumption and performance. While Title 20 and Title 24 California Building Energy Efficiency Standards do not include provisions on air cleaners, the CFR does. The federal appliance standard requires all air cleaners manufactured in, or imported to, the US to comply with the energy performance requirements, meaning any product available for purchase in California will meet the regulations listed below.

Table 4: Federal Code Minimum Integrated Energy Factor Requirements for Air Cleaners[6]

Product Description	IEF ($PM_{2.5}$ CADR/W) Tier 1	IEF ($PM_{2.5}$ CADR/W) Tier 2
10 ≤ $PM_{2.5}$ CADR < 100	1.69	1.89
100 ≤ $PM_{2.5}$ CADR < 150	1.9	2.39
$PM_{2.5}$ CADR ≥ 150	2.01	2.91

Source: US DOE, Office of Energy Efficiency & Renewable Energy, Appliance and Equipment Standards (10 CFR Part 430.32 (ee))

[6] The code defines an air cleaner as a consumer product that: (1) Is a self-contained, mechanically encased assembly; (2) Is powered by single-phase electric current; (3) Removes, destroys, or deactivates particulates and microorganisms solely by means of ultraviolet light without a fan air circulation; and (5) Excludes central air conditioners, room air conditioners, portable air conditioners, dehumidifiers, and furnaces.

The minimum federal standards are expressed as an integrated energy factor (IEF) in terms of $PM_{2.5}$ clean air delivery rate (CADR) per watt (CADR/W). CADR is the measurement of the initial cleaning performance of a filter with respect to specific types of fine particulate ($PM_{2.5}$) pollutants. Tier 1 performance standards went into effect December 31, 2023. And Tier 2 will supersede Tier 1, effective December 31, 2025. Tier 2 is the current minimum specification criteria for ENERGY STAR qualified room air cleaners (EPA, ENERGY STAR Program Requirements for Room Air Cleaners 2022). The state of California developed an energy characterization for room air cleaners, eTRM, which will be used to calculate the energy savings associated with air purifiers (eTRM: CA Energy Efficiency Measure Data 2024).

While room air cleaners are the only devices in this study that have published standards for energy efficiency, the EPA has been working on an ENERGY STAR specification for medical imaging equipment (MIE) for over a decade. In January 2014, the EPA launched the development of the ENERGY STAR specification for MIE with the MIE Preliminary Test Method. The primary objectives of the ENERGY STAR specification included: 1) providing uniform efficiency testing standards, 2) providing purchasers with the means to identify the most efficient MIE, and 3) providing tools and information for designers and managers looking to improve efficiency of MIE operations (EPA 2014). The preliminary test method was developed in collaboration with the Department of Energy and was based on the European COCIR test procedures. In August 2014, EPA released the Final Draft Test Method for Determining Medical Imaging Equipment Energy Use. The MIE included in the scope were CT's, X-rays, MRIs, mammography equipment, nuclear imaging (PET), and ultrasound imaging/sonography equipment. No further developments of the ENERGY STAR specification were announced until 2022.

In November of 2022, renewed interest in the efficiency of medical imaging equipment led to the release of the EPA's ENERGY STAR MIE Discussion Guide. This document was the first step in the renewed effort to develop an ENERGY STAR specification for MIE. The discussion guide included the same equipment identified in the scope of the original testing specification released in 2014 and identified the equipment types sold in significant quantities as well as equipment types with the potential to save significant energy per device. EPA sought stakeholder input on a number of questions regarding the equipment included and excluded in the scope, power management of the various MIE proposed, technologies and functionalities that could drive lower energy consumption, and the willingness of stakeholders to share energy data (EPA 2022). In May 2023, EPA released Draft 1 of the MIE Version 1.0 Specification and Testing Method and following nearly a year of stakeholder engagement and soliciting feedback, released the second draft of the specification and testing method.

In the most recent draft, the ENERGY STAR specification does not address all MIE on the market and instead is limited to only MRI machines. The specification focuses on putting machines into low power or off modes during non-operational hours. It does not address active or non-active modes during operational hours. The second draft of the specification moves all non-MRI devices out of Version 1 due to a lack of data to properly address the energy criteria (EPA 2024). While MRI machines are a primary focus of the specification, its publication is intended as a roadmap for industry stakeholders to collect and incorporate data for other modalities in the future. This specification also standardizes and defines the terminology of operational and non-operational modes, seen in Table 5. The varying terminology between manufacturers can make it confusing to

understand when savings are available. Power save, ready to scan, and scan mode are all relevant during operating hours, which EPA does not presently address. In order to qualify for ENERGY STAR certification, MRI machines must go into an automatic power save mode at a ten percent reduction, or greater, in electrical demand compared to the ready to scan mode. Additionally, during non-occupied time, when the product is not in operation, the unit must be able to reduce its power consumption by 25 percent or more (EPA 2024).

Table 5: Operating Modes and Periods Defined by ENERGY STAR

Mode	Definition
Off	The system is shut down with ac mains off, according to the user manual. The system consumes no energy.
Low power	This mode applies to non-operating hours. It is manually or automatically activated by the user and represents the minimum energy consumption state that the user can select according to the user manual. The power consumption is lower than Ready-to scan and higher than Off mode.
Power save	This mode applies to operating hours and is automatically activated by the product in its as-shipped state to consume less energy than Ready-to-scan mode while maintaining the ability for the product to quickly re-enter Ready-to-scan mode.
Ready-to-scan	This mode represents the state of the system between individual scans, where no scan has been prescribed (e.g., during patient handling, data archiving, examination planning, or contrast agent injection). This mode does not include potential mechanical movements such as X-ray tube rotor or gantry rotation.
Scan	The system is actively scanning the patient to generate images. The computing system interprets the data and generates the image. This mode also includes any potential mechanical movements such as X-ray tube rotor or gantry rotation.
Non-operating hours	Daily times/hours outside of operating hours as defined by end users
Operating hours	Daily times/hours that a business provides for pre-scheduled and walk-in appointments, including emergency care, where the use of medical imaging equipment can be expected.

Source: (EPA, ENERGY STAR Version 1.0 Medical Imaging Equipment, Draft 2 2024)

The ENERGY STAR specification was informed heavily by COCIR; the nonprofit European Trade Association representing the medical imaging, radiotherapy, and electromedical industries. COCIR

has created a self-regulatory initiative for MIE in response to a directive that allowed the Energy Commission to place eco-design requirements on any group of products that utilize energy. It was believed that a self-regulatory initiative would be more beneficial to the market since it would "avoid potentially negative business impacts" (COCIR 2018). The members of COCIR include companies and national trade associations in the medical technology space, including the manufacturers actively part of the US medical device market (COCIR 2023).

REGULATION AND ACCREDITATION OF CALIFORNIA HEALTHCARE FACILITIES

In California there are a handful of regulations that could include information on energy consumption or efficiency requirements. The project team reviewed the following codes and regulations to see if there was relevant information pertaining to energy consumption, energy efficiency, and hospital requirements. The California Code of Regulations was examined to understand if hospitals had standby equipment requirements. This was followed by a review of the 2022 California Green Building Standard to see if there were any efficiency requirements for hospitals. The HHS and the HCAI were reviewed to better understand the healthcare sector in California. Information from the HCAI was also reviewed for information on pressing healthcare discussions.

Through the research, no regulations or standards were found that address energy, or energy efficiency in these devices, outside of air purifiers and the soon to be ENERGY STAR specification for MIE. The team did not uncover any regulations pertaining to standby equipment in hospitals. However, it is possible that regulations exist, and the project team did not discover them through the literature review.

Existing Research on Medical Device Energy Consumption and Use

This section covers a review of market developments, findings, and insights from existing research on medical device energy consumption. While most of the research reports and white papers reviewed include studies in hospital or healthcare facilities, the team also reviewed three studies in residential settings. As stated above, recent market developments have created increased interest in the medical device space.

HEALTHCARE FACILITIES

Research on medical devices in healthcare facilities has heavily focused on MIE. One challenge in analyzing the energy consumption of MIE and synthesizing findings from existing research is the lack of standardization or definition of operating mode nomenclature. The nomenclature used to describe times when the equipment is not in active use differs between manufacturers, and even models of the same manufacturer. Similarly, it also differs in the research reports and findings that have attempted to analyze or quantify the energy consumption of these devices in various operational modes. Common terms used to describe non-active modes include idle, standby, low power, power saving, and even off in the case of MRI machines which require constant power for cooling the magnets. Research conducted by Lawrence Berkeley National Laboratory (LBNL) on behalf of the CEC in 2011 found minimal information at the time regarding energy use of medical equipment and miscellaneous electrical loads in hospitals, indicating a need for more research in this area (Black, Lai, et al. 2011). Since then, there has been additional interest in the energy consumption of medical devices, however, research on end-use power consumption, operational modes, and typical usage patterns has been limited.

Following LBNL's review, a study performed in the San Francisco Bay Area across a handful of Kaiser healthcare facilities found that, during unoccupied hours when patients were not being seen or treated, plug loads in medical office buildings accounted for half of the peak load, with a range of 0.15 W/ft^2 to almost 0.40 W/ft^2 between metered hospitals. The plug loads were metered via individual circuits to provide the most granularity and varied significantly between different hospital departments (Ruecker and Guity 2013). Researchers at Wichita State University studied the life cycle energy associated with CT scanners. The researchers recorded and analyzed the energy consumption associated with various operational modes for comparison. Interestingly, and unlike previous studies, the researchers included a "partial mode" to account for the time spent positioning the table and scouting images. This emphasizes the variability in how the energy can be examined for medical imaging equipment. Researchers found that greater than 80 percent of the machine's total energy consumption occurred while the machine was in idle mode and that partial mode accounted for 10 percent of the total energy consumption of the machine (Esmaeili, et al. 2015). These research findings closely align with research conducted by PE International. PE International collected CT scanner data in low power, idle, and scan mode for a collection of manufacturers that participate in COCIR. The researchers found that setting the machines to low power mode for 12 hours during non-operational hours reduced the total energy consumption of the CT scanners by approximately 30 percent (Herrmann and Rock 2013).

Researchers studying the energy consumption of MRI machines at multiple healthcare facilities found that 80 percent of the total energy consumption occurred while the machine was in idle mode at one site while only 30 percent of energy consumption occurred during idle mode at another site. The same study found that 70 percent of energy consumed by a CT scanner occurred while the device was in idle mode. The average power consumption during this time was 2-3 kW. When the CT scanner was placed into a low power mode, the power consumption dropped below 1 kW. This study highlights the significant energy savings associated with setting devices into low power modes when they are not active. Interestingly, the researchers note that while the devices in this study had the capability to be set to low power modes, users were not using these modes (Easty, et al. 2018). In a different study, researchers metered MRI and CT scanners in various operational modes and found similar results. Of the modes examined in the study, active, idle, and off modes were most relevant. Researchers defined "active" mode as time when the patient was in the room and the machine was ready, idle mode as time when the system was on and the patient was not in the room, and off mode as time when the system was off, unable to immediately scan, but still consuming energy. Two thirds of a CT scanner's energy consumption is in the idle state and a third of the energy needed to power an MRI machine is for cooling in off mode. The metering also showed varying load shapes: MRIs have a fluctuating load shape with more variance throughout the scan duration, while CTs typically have one peak above a lower, consistent power consumption over the scan duration (Heye, et al. 2020). Radiology research centered around MRI and CT, while research on PET was scarce. Previous studies found that CT and PET scanners are often used in tandem to generate a quicker and more accurate diagnosis for a patient, while reducing patient exposure to radiation (Townsend 2008). Advances in efficiency will likely be seen in combined systems, due to their increasing popularity.

Of the existing research and reports reviewed, the project team found little information on the energy consumption of X-ray machines. While the energy consumption of an individual X-ray machine is lower than that of CTs and MRIs, the total energy consumption and savings potential associated with these devices shouldn't be disregarded. One report from COCIR states 85 percent of annual energy

consumption of X-ray machines is in the ready to scan state, with 12 percent is in low power mode and three percent is scanning. The COCIR report indicates 51 percent energy savings can be achieved if X-ray machines are switched to low power mode, night hours during weekdays and weekends. The savings are even greater in off mode during weeknights and weekends, with up to 64 percent of energy reduced (COCIR 2015). Using existing low power modes where present and advocating for low power modes where they aren't currently present, is essential to reducing the energy consumption associated with MIE.

In another LBNL study, researchers aimed to quantify energy consumption associated with medical devices in hospitals. They found that common, smaller devices consume large amounts of energy in aggregate. For example, the ventilators metered in the study were found to have an average power consumption between 20W and 140W. The average power consumption between the manufacturer and model varied. This was also seen with the hemodialysis units metered. The average power consumption ranged from 48W to 504W (Black, Lanzisera, et al. 2012).

In addition to MIE, the project team scanned and reviewed existing literature for research or studies on the energy consumption of infusion pumps and dialysis machines. Research quickly found that these machines have not been studied in the residential space and the research in the commercial space has been limited. The project team did not find any existing research focused on reducing the energy consumption of infusion pumps but found one journal article studying the ability to power portable medical devices with energy harvesting from human movement. While the study was not necessarily focused on quantifying energy consumption of the devices studied, it did provide power consumption information on insulin infusion pumps: 12W per unit when the device is on, and even indicated these devices may be a good candidate for harvested energy because they require minimal power to operate (Paulo and Gaspar 2010). While this study indicated rated power information for an insulin infusion pump, it did not address the broad range of infusion pumps on the market today.

The project team also found that existing research on hemodialysis has not been centered around energy consumption. In one piece of literature, researchers created a model to estimate the resources, water, and power needed to perform dialysis for a varying number of patients in a dialysis center. The model included the dialysis machine and auxiliary systems, like sterilization. The study found that energy consumption is highly dependent on the treatment and techniques used and more than 50% of the total energy consumed during the process is associated with the dialysis machine itself (Wandler, Bai and Wolfgang 2020). This aligns with conclusions that dialysis machines are resource intensive units, consuming large amounts of power and water and creating substantial amounts of waste, compared to other medical therapies. The energy consumption associated with a single dialysis treatment can be as high as 18 kWh, depending on conditional factors (Noruisiene, et al. 2022). Different dialysis practices should also be examined in future works to understand when and where energy consumption can be reduced in dialysis treatment. Using low power modes when appropriate on this equipment could reduce energy consumption substantially when these machines are not in use.

Existing research in healthcare facilities highlighted concerns about metering equipment because of patient privacy, patient care disturbance, and device mobility throughout the hospital. To reduce these risks, a prototype device that could distinguish between power modes without measuring current invasively was established for power data collection (Black, Lai, et al. 2011). Patient privacy is a concern in hospitals, so long-term metering and data collection is typically avoided to reduce

unnecessary risk. Determining new methods to collect data without risks of network disturbance are key to collecting data on medical equipment in the future.

RESIDENTIAL AND HOME-HEALTH CARE

While they consume less energy per device in comparison to medical devices used in healthcare settings, residential medical devices may have significant energy savings opportunities when considered in aggregate. The project team reviewed existing literature to characterize the energy consumption and savings potential of these devices.

CPAP ventilators are traditionally used to treat sleep apnea, providing continuous airway pressure in case of temporary cessation of breathing. CPAP use is highly dependent on the patient's willingness and commitment to using the device. CPAP compliance, or regularity of use, is monitored by both physicians and insurance companies. Compliance refers to whether the patient is using the device as prescribed and is generally defined as in use for at least four hours a night for at least five nights a week (Summer and Wells 2024).

Monitoring CPAP use and compliance is important, as regular use is associated with increased benefits and health. A variety of studies have indicated that patient adherence to CPAP compliance decreases significantly during the first year of treatment, with compliance reported to be as low as 30 to 60 percent (Weaver and Sawyer 2010). One study, which investigated intervention strategies for improving CPAP compliance, reported an average use of 4.9 hours per night in the uncontrolled, or baseline, group (Malhotra, et al. 2018).

Physicians monitor use patterns of CPAP devices as part of patient treatment, as well as for insurance purposes. Information about compliance may be used to determine whether a patient's insurance policy will cover the doctor prescribed CPAP therapy. CPAP compliance, and how to improve it, has been widely studied by the healthcare community. Results have shown a wide range in operational use of CPAP devices, as well as relatively low compliance metrics. The metadata from these studies associated with CPAP monitoring is limited to time of use, residual respiratory events, and leaks. While the data available from CPAP monitoring is specific to routine clinical care, there was no electrical or power consumption data included in these datasets that could be used for analysis in this report. Including power measurements in the monitoring profile, while useful for the potential to improve energy consumption, wouldn't be valuable to physicians who are more concerned about providing the best possible treatment and care.

One study reviewed by the project team assessed the population in the US that is electricity-dependent for the use of durable medical equipment. The study contained information on the quantity of at home medical devices in the US, and the research identified that users of residential medical devices are a vulnerable population because they have an increased burden from higher electrical loads, while also facing increased risks during power outages (Molinar, et al. 2017).

Additionally, LBNL conducted research to understand the power consumption of various plug loads. The first study reviewed the reduction of standby power. The research included oxygen concentrators and CPAP ventilators in a residential setting. It is unclear what the correlation is between adjusting oxygen flow rate and power consumption, but this was noted as a future energy saving opportunity. User adjustments also exist for CPAP ventilators, but with regards to temperature and humidity setpoints (Meier, et al. 2020). Another study estimated energy consumption of a CPAP machine at 80 kWh/year/unit. However, this value is highly variable due to usage and device settings, as the

user inputs for heating and humidification drive energy consumption (Rainer, Meier and Hosbach 2021). Both studies acknowledged that educating healthcare providers on how users can reduce their device energy usage is important in achieving behavior change as healthcare providers are in a unique position to instruct patients on use of devices including energy saving power management strategies.

The project team reviewed a market study on air cleaners to understand the devices used in the state. The study found that, due to increasing concerns about pollution and recommendations to patients with lung related diseases and allergies, the air cleaning market is expanding (TechSci Research 2019). An extensive ENERGY STAR specification exists for air cleaners as do efficiency programs, indicating a mature market. Heating pads do not have an ENERGY STAR specification and have not been researched in this context. The literature found addressed personal comfort systems, which heating pads fall within, but the focus has been on addressing building setpoint reductions and thermal comfort (Luo, et al. 2018) (Rawal, et al. 2020) associated with the use of heating pads, not energy consumption or methods to reduce energy consumption.

SUMMARY

Medical device energy consumption is highly variable. There are different operational modes, run hours, quantity of patients treated, and types of operational use. Understanding the market that a program is designed for is essential to create value for both the customer and the state.

Devices left in ready to scan or operational modes when low power modes are available are using significantly more energy than required. This emphasizes the need to reduce energy consumption when the device is not in use. Implementing low power modes where applicable could reduce the non-active energy consumption. Educating equipment users on how to activate these modes is essential to seeing benefits. It is equally as important to ensure new equipment purchased has low power mode capabilities built in, and if possible, is automatically set up to reduce user error.

Medical devices that can be used in the residential space have not been studied outside of a safety and energy resilience lens. Literature for devices that fall in this market characterization was mostly found through research in commercial spaces. Of the devices included in this study, MRIs have the most research in this area, which is likely spurred by increased federal interest in reducing their energy consumption.

Patient privacy is also a concern in hospitals when data collection and metering are deployed by an outside source. Data collection methods that have no risk for data breaching have yet to be proven.

Operational and Technical Manuals

Manufacturing of commercial medical equipment is primarily done by a handful of companies. These manufacturers have created operator manuals that contain detailed information and instructions for using devices. Some manufacturers make their manuals publicly available, while others must be requested from manufacturers' representatives or accessed from a portal, which often comes with the purchase of a device. The manuals can be substantive in size, but typically have a dedicated chapter for initiating start-up, shutdown, energy consumption modes, warnings for use, and sometimes estimates for the time required to move between modes. It is important that users review the manual for each device, as particular devices have specific information regarding how to start up and shut down. For example, MRI machines require continuous cooling and, if they lose cooling, the

magnet will be irreparably damaged (Schneider Electric 2018). The operator manuals for MRIs specifically mention that the device should not be completely shut down unless necessary. Guidance varies by device type and can vary between manufacturers, so it is important to review this information.

Through this review, it was determined that some devices have low power consumption, while others do not. Devices that have this capability may adjust automatically and others may require a technician to manually set the device back. Information on the duration of time to remove a device from low power mode is often not easily accessible, if at all available. Ensuring this information is available and accurate is pertinent in realizing energy savings through power management. It was also determined that manufacturers use different terminology to describe similar actions. Overall, it is challenging to locate information on different energy modes of medical equipment. Terminology has not been standardized for the different energy consuming modes, however, ENERGY STAR is working to establish terminology and meter equipment (LeBar, et al. 2023). The residential medical device market is saturated with manufacturers for many of the devices examined. Baxter, ResMed, and Medtronic are some of the manufacturers for the residential devices reviewed. The project team researched energy consumption and different operational modes of devices, but the lack of understanding surrounding the energy use profiles of these medical devices resulted in a lack of information around energy consumption associated with various power modes. Of the device manuals reviewed, the CPAP and ventilator machines both had power save mode options. The ventilator manuals reviewed did not have information on power save modes readily accessible. The review of existing manuals was not exhaustive. While the information was not readily accessible, it may exist. It is important to acknowledge that the information, where accessible, was within operator manuals and not provided on the manufacturer site. Increasing the accessibility of documentation could help reduce energy consumption where the modes already exist.

Insight and Feedback from Stakeholders

Market stakeholders including healthcare professionals, insurance providers, device manufacturers, and others specializing in energy and facility management in the healthcare sector were consulted to obtain a better understanding of the medical device landscape, equipment usage and practices, and opportunities and barriers to greater energy efficiency.

Conversations with government agencies, national labs, and various actors in healthcare facilities gave light to the market's state from various perspectives. While an ENERGY STAR specification for imaging equipment has been in the works for nearly a decade, the interests of healthcare providers were more heavily focused on equipment cost and research opportunities. Their focus has shifted, with a heavier emphasis placed on the link between climate change and healthcare. Hospitals increasingly have goals to reduce their climate impact through energy use and emissions reduction targets. While slower than other technologies, movement regarding energy efficiency in the US medical device market has been supported by both DOE and the EPA and has come in part due to progress from manufacturers that already comply with increasingly stricter international guidelines. To date, research and efficiency efforts surrounding medical devices have been heavily focused on MRI scanners due to their significant energy consumption. Stakeholders shared that, while healthcare facilities are becoming increasingly energy conscious and setting sustainability goals, much of that effort has been focused on the sustainability of consumables and has not been as heavily focused on plug loads of medical devices.

The research team asked stakeholders about their procurement processes to understand whether opportunities were available to reduce energy consumption through the purchase of new devices. Stakeholders shared that the procurement process for large medical equipment varies between hospitals and is largely dependent on capital spending. Planning for the purchase of new medical imaging equipment often begins up to five years in advance. Priorities for purchase include equipment that has reached end of life, has enhanced capabilities in line with the hospital's specialty, or provides the opportunity for a hospital to be the first to research or perform a specific medical procedure. Education on what devices are more energy efficient or have greater load management capability is desired, even though sustainability is often a very small part of the process, if it is considered at all. Hospitals are not often tied to a specific manufacturer of medical equipment, but the benefit of technicians already familiar with a manufacturer's software was mentioned, as well as physician preference. Sustainable procurement policies can and are being developed to provide guidance to the procurement teams, but guidance on what to recommend is needed. These processes create a barrier to the adoption of emerging energy saving features and devices.

In addition to the current market landscape and procurement processes, market stakeholders working in healthcare facilities shared insights about various barriers to medical device efficiency. It was noted that, beyond efficiency measures in the device, behavior of device operators has a significant, if not the largest, impact on energy use of the device. Device operators hold the responsibility of setting the device to lower power modes or turning the device off when not in use. Given this responsibility, radiologists and researchers familiar with the energy saving features of the technology have developed trainings regarding those features and best practices to aid in increasing efficiency of existing devices. In addition to behavioral factors within facilities, stakeholders identified several barriers on the manufacturer end. To date, manufacturers have had little incentive to increase the efficiency of their devices, as there has been minimal pressure from the end users they directly work and communicate with most often. Other market actors looking to uncover potential energy savings opportunities have struggled to get data directly from manufacturers. In addition to these barriers, it was shared that every manufacturer has their own respective names for different operation modes, as well as differing protocols, complicating a standardized efficiency effort for the end user. Market actors expressed interest in utility programs incentivizing efficient medical device measures similarly structured to existing incentives for other efficient equipment purchases that healthcare facilities already take advantage of, such as lighting and HVAC.

While there are ongoing studies metering medical imaging equipment to better understand usage and loads, stakeholders continuously stressed the need to keep patient care and privacy top of mind. Lack of data has posed challenges to the development of energy savings in operating modes in a way not seen in most other technology categories. This scenario results in targeting most energy saving opportunities during non-operating hours when patient care and privacy are of less concern.

REFERENCE TABLE FOR DEVICE USERS AND OPERATORS

While identified as a project objective during initial research, the need for a reference table of power management instructions was confirmed through conversations with stakeholders. The reference table is included in Appendix A and represents one way to display information on how to activate lower power modes for technicians who operate the equipment.

When asked about the advantage of such a resource, industry professionals working in healthcare facilities verified the usefulness and benefit of it. The table was constructed to show technicians if lower power modes are available within a variety of different devices, and if so, how to activate them. The table was also identified as a resource that could be used during the procurement process by stakeholders. Emphasis was placed on including all devices on the market and revising the table when new devices arrive on the market. Of all devices included in the table, the imaging equipment had the most information publicly available. Stakeholders mentioned the importance of making the table accessible, filterable, searchable, and ideally hosted on a public webpage, similar to existing qualified product lists.

For each device model listed, the reference table indicates whether low power modes can be activated automatically or must be activated manually and includes the duration of time to move between a lower power mode and a ready to scan mode. Guidance directly from the operator manual on how to activate the lower power modes is included in the table for easy reference. The documentation that contains this information is often lengthy, so additional information directing users to the document hyperlinked is provided to increase accessibility. The relevant section and page(s) containing the guidance is also included. Additionally, directions to information on how to transition the device out of a lower power mode to a ready to scan mode and to show when the source was published was included.

The reference table is not comprehensive of all devices on the market and instead illustrates what information is important for users operating these devices to effectively manage power and energy consumption, and how this information may be formatted in an accessible and digestible manner.

Energy Consumption and Savings Potential

Commercial Medical Devices

The following section presents the findings on the energy consumption and savings potential of medical devices within healthcare facilities including MRI machines, CT scanners, X-ray machines, PET scanners, infusion pumps, and dialysis machines.

MRI MACHINES

As noted above, energy consumption of MRI machines is perhaps the most widely studied of the devices in this market characterization. Through stakeholder engagement and review of existing research, the project team learned about the current energy saving opportunities for these devices. One energy saving strategy associated with commercial-grade medical imaging equipment is the curtailment of power when the equipment is not in active use. Being able to institute low power or power save modes when the machine is idling, or not in use, can result in massive energy savings. Managing parasitic loads when the equipment is off can also result in high energy savings.

To quantify the energy savings potential and impacts on MRIs and other MIE, it is important to understand how they operate, when they’re in use, and how medical service professionals leverage MRIs in the diagnostic process.

MRI machines, among several other parameters, are rated on their magnetic strength, using units of Tesla (T) for quantifying the magnetic field. MRI machines are rated between 0.5 and 3 T, where typically, but not always, the imaging quality and demand profile increase with magnetic strength.

The magnetic strength of the MRI dictates what scans are preferred by doctors and technicians. MRIs on the high end, such as a 3 T MRI machine, are typically used for small field image viewing, such as for small joints or the brain. For wide scans or images including the full body, 1.5 T MRIs are preferred. Electrical demand has a strong correlation with magnetic field strength. MRIs with higher rated magnetic fields will have larger power draws. The rated power range for MRIs is between 50 and 100 kilovolt-amps (kVA) (NREL 2023). Figure 1 shows the MRI machine market share based on magnetic strength. The market share is dominated by 1.5 T MRI machines, accounting for 60 to 75 percent of all MRIs currently on the market (NREL 2023).

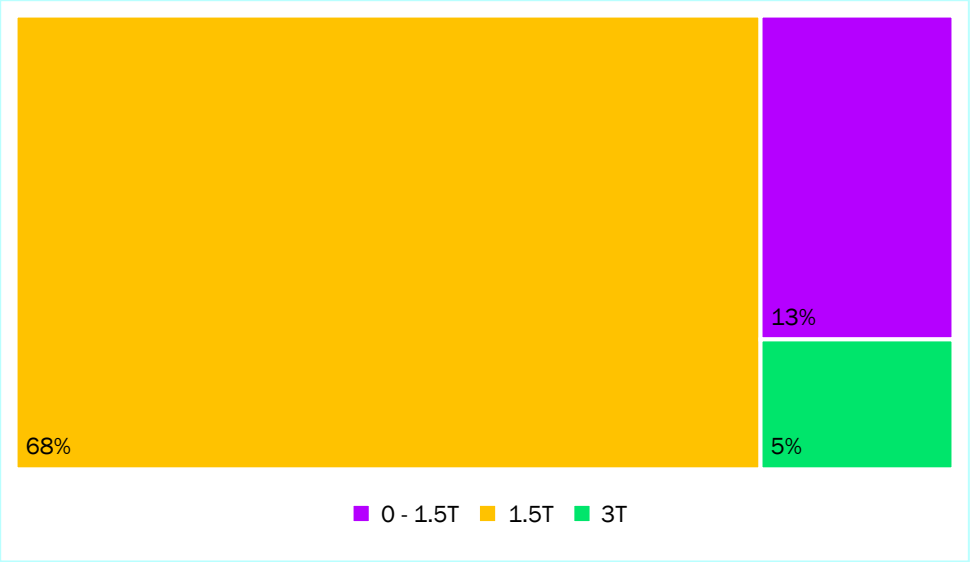

Figure 1: US MRI market share based on magnet strength.

Source: (NREL 2023)

The use of MRIs, the duration of the scan, and the amount of time MRIs are in scan or ready-to-scan mode differs depending on the scanning event and examination region. These scans can last from 37 minutes for an abdomen examination to 73 minutes for a whole-body scan. On average, a single patient scan can last 51 minutes and consume 20.3 kWh (Heye, et al. 2020).

Power curtailment between the various system states is the largest opportunity for energy savings associated with MRIs. Continuous power to an MRI machine is necessary to cool the magnets even in an off state where it draws 9.3 kW and can account for 34 percent of the entire machine's annual energy consumption, as detailed in Table 5 (NREL 2023).

Table 6: Medical Imaging Equipment Definition of Scanner Activity System States

System State	Definition	Average Power Consumption (kW)	Average Distribution of Daily Energy Consumption[7]
Active	The time period during which an MRI is used to examine a patient. This includes scan preparation and planning, data collation and image collection, as well as the scanning event.	22.3 kW	32%
Idle	The time interval between active system states. Typically represented as the time period between patient examinations.	14.6 kW	34%
Off	The sequence of time when the scanner is powered down and off. Ancillary equipment may still draw power and immediate scanning is not possible as a power-up sequence of several minutes is needed before scanning.	9.3 kW	34%

Source: (NREL 2023)

On average, an MRI machine is estimated to consume 111,000 kWh annually. Being able to manage the machine in low power mode in idle and off mode can result in an estimated 21.8 percent, or approximately 24,000 kWh in annual energy savings per device (NREL 2023, COCIR 2018).[8]

In the breakdown of where MRI machines are and how they are used, it is important to note which type of facility employs medical imaging equipment. Through review of the EIA CBECS, it was determined that 80.5 percent of inpatient healthcare facilities have an MRI. A further breakdown of the imaging equipment surveyed in EIA CBECS is detailed in the table below.

Table 7: Percentage of Buildings with Medical Imaging Equipment by Building Type and Equipment Type

Building Type	MRI	X-Ray	CT Scan
Office	1.1%	4.2%	0.5%
Outpatient Health Care	34.4%	75.0%	25.0%
Inpatient Health Care	80.5%	100.0%	92.7%
Strip Shopping Center	0.0%	33.3%	9.1%

[7] Power consumption and load profile for MRIs can vary depending on what type of healthcare facility they are in (hospital vs. outpatient office) and location within that healthcare facility (ICU vs. General Radiology Department). In developing these estimates, NREL combined data from a number of other third-party studies to arrive at an 'average' distribution of daily energy consumption for MRIs.

[8] The potential savings estimate is sourced originally from COCIR, Self-Regulator Imitative for the Ecodesign of Medical Imaging Equipment, Status Report 2018.

Source: EIA CBECS (2018)

The OECD tracks and records a number of economic and financial, environmental, and statistical data points for equitable analysis across countries. One of the datasets that was used for analysis for this report was the Healthcare Utilization dataset which provides reports and aggregates on key aspects of hospital and inpatient facilities (OECD 2012). Through review of national data and then extrapolation to the state of California based on the distribution of hospital beds across the country, it is estimated that the state has approximately 1,300 MRIs in active use. Nearly 4.2 million MRI scans are conducted each year, with 53.4 percent of them occurring in hospitals.

Based on the average annual energy consumption per device, the estimated savings potential, and the number of devices in California, the estimated total annual energy consumption of MRI machines is 141.8 GWh and the estimated annual savings potential is 30.9 GWh.

As the average lifetime of an MRI is estimated to be 11.5 years,[9] it is assumed that 8.7 percent of the market turns over annually (NREL 2023).

CT SCANNERS

CT scanners, another MIE device, have similar operating parameters and system stages to MRI machines and similar energy intervention strategies can be applied.

In the breakdown of where CT scanners are and how they're used, it is important to note which type of facilities employ MIE. Review of the 2018 EIA CBECS data determined that 92.7 percent of inpatient healthcare facilities have a CT scanner and approximately 25 percent of all outpatient healthcare facilities have one. A further breakdown of the imaging equipment surveyed in EIA CBECS is detailed in Table 7.

The use of CT scanners, the duration of the scan, and the amount of time CT scanners are in scan or ready-to-scan mode differs depending on the scanning event and examination region. These scans can last from seven minutes for a neck or spine examination to 51 minutes for a whole-body or intervention scan. On average, a single patient scan can last 16 minutes and consume 1.2 kWh (Heye, et al. 2020). The rated power range for CT scanners is between 50 and 100 kVA (NREL 2023). While a CT scanner is in idle or standby mode it can draw between two and three kW. Similar to MRI machines, CT scanners require cooling.

One study found CT scanners consumed, on average, 26,226 kWh annually with 54 percent energy consumption occurring when the machine was in idle mode, Figure 2 (Heye, et al. 2020). In this study, researchers defined the system off state as the following: the system is powered down but may still consume energy owing to ancillary systems; immediate scanning is not possible, and power-up sequence of several minutes is needed before scanning. Results show 15 percent of the annual energy consumption occurred while the scanners were in an off state. Another study presented findings from CT scanners metered at two different locations, where researchers found the energy use per month ranged from 3,862.9 kWh to 6,737.6 kWh, equivalent to 46,344 kWh to 80,844 kWh

[9] The NREL data points on MRI lifetime is heavily influenced by the 2018 MRI Buyer's Guide from GE Healthcare. In this literature, GE claims, "50 percent of installed MRI base will be replaced within 11 years of their installation. The average replacement cycle is 11.5 years, ranging from 3-22+ years. The general feeling is that one out of every five MRI systems is older than 10 years."

annually (Esmaeili, et al. 2015). The annual energy consumption of CT scanners in California was estimated using the average of these values to get a baseline annual energy consumption per device of 51,144 kWh.

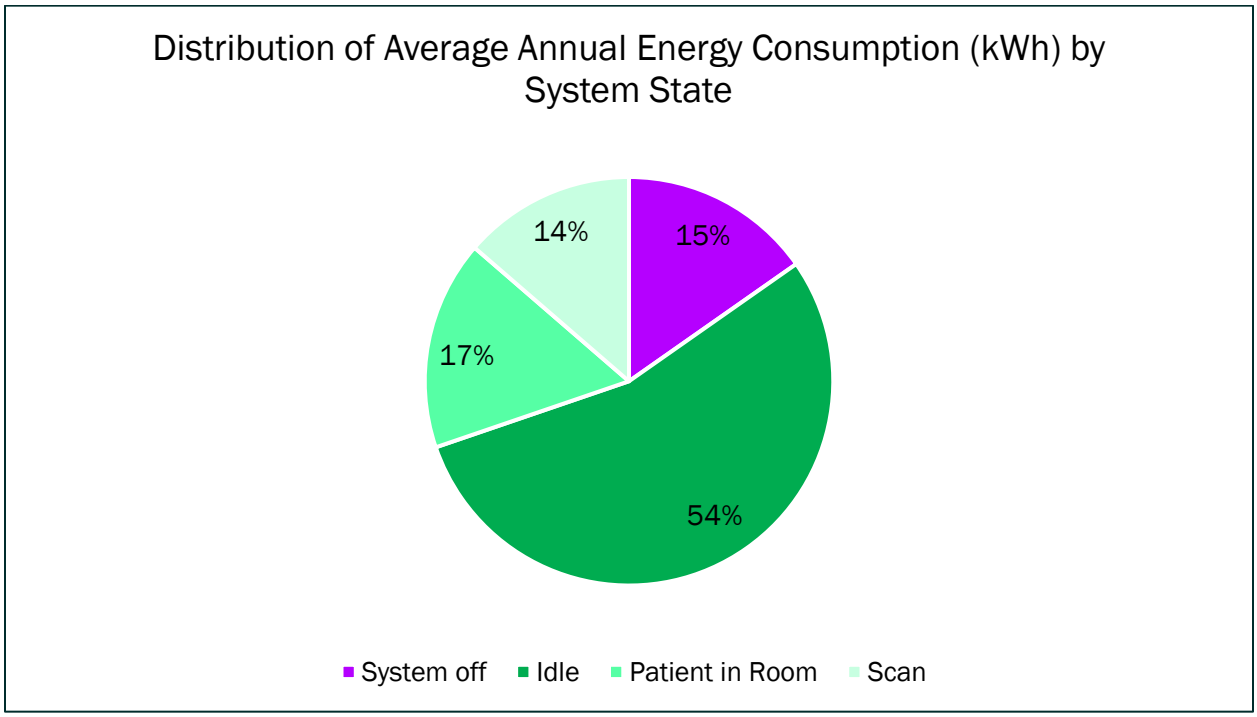

Figure 2: Distribution of average annual CT energy consumption (kWh) by system state.

Source: (Heye, et al. 2020)

Power curtailment between the various system states presents the largest potential energy savings opportunity for CT scanners. A study on CT scanners found savings potential up to 31 percent with effective use of low power modes during non-operational hours (Herrmann and Rock 2013), and with up to 48 percent savings by turning the machine off during non-operational hours (COCIR 2014).

Leveraging the OECD dataset, it is estimated that the state of California has approximately 1,660 CT scanners in active use. Nearly 9.9 million CT scans are conducted each year in California, with 81 percent of those occurring in hospitals (OECD 2012).

Applying a similar savings methodology to CT scanners, annual energy savings are estimated to be 26.3 to 40.8 GWh in the state of California.

X-RAY MACHINES

Unlike MRI and CT Scanners, X-Ray machines are ubiquitous in California hospitals. According to the EIA CBECS data, 100 percent of inpatient healthcare facilities have an X-Ray machine and 75 percent of outpatient facilities have at least one as well (see Table 6). VEIC was unable to find state-specific equipment stock data and instead used national market data to estimate the number of X-ray devices in the state of California. In Europe, COCIR collects and reports market data on a number of MIE types, including X-rays. The Medical Imaging Equipment Age Profile & Density report by COCIR

found the average density of X-ray machines per one million inhabitants in the European Union (EU) to be 25.1, however, there remains a wide range within the EU from 44.3 in France to 8.4 in Portugal (COCIR 2021). With no market data in the US, VEIC assumed the density of X-ray machines within California is slightly higher than the EU average at 30 X-ray machines per one million inhabitants or an estimated 1,169 active X-ray devices within the state.

X-Rays consume an estimated 9,500 kWh annually per device and have a rated power range between 0.5 and 1.5 kVa (Knott, et al. 2017). Review of existing literature indicates energy savings of 51 percent to 64 percent may be realized through power management of X-ray devices during non-operational hours, such as nights and weekends (COCIR 2015). Given the estimated number of devices within California, and the annual energy consumption and savings potential per device, VEIC estimates X-ray machines are responsible for 11.1 GWh annually with the potential to save 5.7 to 7.1 GWh annually through improved power management.

PET SCANNERS

Overall, PET scanners constitute a smaller market compared to the other MIE studied. The project team used data from OECD and COCIR to estimate the number of PET scanners in the state of California. OECD data at the national level was extrapolated to the state of California based on the distribution of hospital beds across the country. COCIR reports the average density of PET scanners per one million inhabitants in the EU. The team used the average density (2.4) to estimate the number of PET scanners based on the population of California (COCIR 2021). Based on these two data sources and approaches, the team estimates there are approximately 94 to 224 PET scanners in California. Evenly distributed between inpatient and outpatient healthcare facilities, PET scanners are responsible for 260,000 examinations annually in the state of California (NREL 2023). Review of existing research and studies did not reveal information on the power consumption or use profiles of these devices. However, given PET scanners have a similar function and use to MRI machines and CT scanners, and MRI/PET and CT/PET combination scanners are increasingly more common, the energy savings measures are likely similar to the other MIE studied, and savings may be realized through power management during non-operational hours.

INFUSION PUMPS

The energy consumption of small commercial-grade medical devices has traditionally been under characterized due to a lack of quality information. Infusion pumps fall under this category but deserve more scrutiny due to the sheer quantity of infusion pumps utilized in commercial healthcare settings. Infusion pumps in a hospital, in aggregate, consume more electricity than MRIs (Black, Lanzisera, et al. 2012).

An inventory of the Stanford University Medical Center's (SUMC's) Stanford Hospital and Clinics (SHC) and the Lucille Salter Packard Children's Hospital (LPCH) in Palo Alto, California yielded 4,779 infusion pumps combined (Black, Lanzisera, et al. 2012). Spot measurements and estimated annual unit energy consumption of these infusion pumps approximated 139 watts and 166 kWh, respectively. Projecting this across the two hospitals, the estimated total annual energy consumption of infusion pumps is nearly 800 MWh.

Given the square footage of these two hospitals, assuming a normalized density of infusion pumps per hospital floor area and extrapolating this over the entirety of the state of California, the project

team estimates there are approximately 1.98 million infusion pumps in active use in healthcare facilities within the state (CEC 2022).[10]

The energy savings potential for infusion pumps was not explored in any literature reviewed by the project team. However, understanding an infusion pump's load profile can assist the investigation on where power curtailment options could provide energy saving benefits. Table 8 provides details on the daily operational settings of infusion pumps in healthcare facilities.

Table 8: Estimated Fraction of Use and Time in Power Mode for Infusion Pumps

Device Category	% of Devices		% of Time in Mode for Used Devices		
	In Use	Not In Use	On	Low Power	Off
Infusion Pump	80.0%	20.0%	83.0%	0.0%	17.0%

Source: LBNL

DIALYSIS MACHINES

In the US, approximately 430,000 patients are dependent on hemodialysis (Agarwal, et al. 2019). In 2022, it was estimated that approximately 3.9 million patients worldwide regularly underwent dialysis treatments (Fresenius 2022).

An inventory of the SUMC's SHC and the LPCH in Palo Alto, California yielded 35 hemodialysis units combined (Black, Lanzisera, et al. 2012). Spot measurements and estimated annual unit energy consumption of these dialysis units approximated 1,220 watts and 163 kWh, respectively. Projecting this across the two hospitals, the estimated total annual energy consumption of dialysis units is nearly 5,705 MWh.

Given the square footage of these two hospitals, assuming a normalized density of dialysis units per hospital floor area and extrapolating this over the entirety of the state of California, the project team estimates there are approximately 15,000 dialysis units in active use in healthcare facilities (CEC 2022).[11]

Additionally, a study commissioned by Kidney International Report observed dialysis machines consuming 3.1 kWh and 92 gallons of water per treatment (Nickel, et al. 2017). Hemodialysis machines require a constant flow of water to operate properly. In the process, water acts as the selected dialysis fluid for diffusion during this renal replacement therapy. Particles are passed from the blood into this dialysate and then rejected from the machine. As a result, hemodialysis machines consume an enormous amount of water. One year of hemodialysis treatment could see as much as 20,000 gallons of water run through the machine.

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[10] The square footage of SHC and LPCH are 900,000 ft² and 260,000 ft² The total healthcare industry's floor stock of 480,002 kft² is sourced from the California Energy Commission (CEC) 2022 California Commercial End-Use Survey, February 28, 2024.

[11] The square footage of SHC and LPCH are 900,000 ft² and 260,000 ft² The total healthcare industry's floor stock of 480,002 kft² is sourced from the CEC 2022 California Commercial End-Use Survey, February 28, 2024.

The energy savings potential for dialysis units was not explored in any literature reviewed by VEIC. However, understanding a dialysis unit's load profile can assist the investigation on where power curtailment options could provide energy saving benefits. Table 9 provides details on the daily operational settings of dialysis units in healthcare facilities.

Table 9: Estimated Faction of Use and Time in Power Mode for Dialysis Units

Device Category	% of Devices		% of Time in Mode for Used Devices		
	In Use	Not In Use	On	Low Power	Off
Dialysis Units	90.0%	10.0%	1.0%	24.0%	75.0%

Source: LBNL

In-center hemodialysis patients receive treatment approximately three times a week, with each session occurring between three and five hours (Mayo Clinic 2023). Based on Table 8, the majority of dialysis machines spend the most time in low power or off mode, indicating limited energy savings potential through power management.

Where spot measurements of energy consumption were observed for baseline equipment, energy-efficiency solutions have not been studied in greater detail. Therefore, the project team could not identify efficient models or a baseline to quantify the energy savings potential of dialysis machines.

COMMERICAL DEVICE SUMMARY

Much of the research thus far has focused on MIE, a subset of the commercial medical devices reviewed in this study. While MRIs are thought to be the greatest energy consumers and as such, have the highest potential for energy savings, our preliminary estimates indicate this may not be the case. While infusion pumps have a comparatively small (166 kWh) energy consumption per device, the sheer number of estimated devices in California leads to a total energy consumption nearly twice that of MRI machines. While the project team did not uncover any existing work on energy-efficiency improvements or power management strategies of these devices, incremental improvements could lead to significant energy savings in the state of California. Further research and stakeholder engagement may help quantify the magnitude of these savings. Based on the review of existing literature and initial estimates, the project team also found that, while the total annual energy consumption of CT scanners was less than that of MRI machines, the overall energy savings associated with improved power management of CT scanners is greater than that of MRI machines. This may be explained by the need for continuous power to cool the magnets of an MRI machine even in off modes. Additionally, further research is needed to characterize the energy consumption of these devices based on the various usage profiles. Savings estimates do not account for the effectiveness of technician training, education, and policy around switching MIE machines into low power modes or the market penetration of equipment with capability to automatically set back into low power mode. Additionally, VEIC found dialysis machines have a significantly smaller energy consumption in comparison to the other devices studied, and previous studies indicate these machines already spend the majority of time in low power or off modes, leading to negligible energy savings potential, if any.

Table 10: Summary of Commercial Medical Device Findings

Device Type	California Equipment Stock, Devices	Total Market Baseline Annual Energy Consumption, GWh	Overall Annual Market Savings Potential[12]
MRI Machines	1,277	141.8	30.9 GWh
CT Scanners	1,661	85.1	26.3–40.8 GWh
X-ray Machines	1,169[13]	11.1	5.7-7.1 GWh
PET Scanners	94–224	Unknown	21.8–48%[14]
Infusion Pumps	1,977,524	328.3	0
Dialysis Machines	14,483	2.4	0

Source: Project Team

Residential Medical Devices

The following section presents the findings on the energy consumption and savings potential of residential and home-health medical devices, including air cleaners (purifiers and ionizers), CPAP machines, ventilators, infusion pumps, dialysis machines, and heating pads.

AIR PURIFIERS

The market and technical characterization of air purifiers may be the most mature of any of the medical devices studied in this report. The baseline is well-established through governance in federal codes and standards. Their energy performance and savings characteristics are detailed extensively through ENERGY STAR's program requirements. Air purifiers are a widely accepted prescriptive offering across jurisdictions nationally, characterized in the California eTRM.

There are several different applications of air purifiers currently available on the market. This report focuses on electronic portable air purifiers and not filter-based air cleaning units integrated into duct work that rely on the HVAC system to circulate airflow.

[12] For devices where energy savings potential is indicated as "0," the project team could not establish any energy savings potential, either through power management or energy efficiency.

[13] The Medical Imaging Equipment Age Profile & Density report by COCIR found the average density of X-ray machines per one million inhabitants in the EU is 25.1, however, there remains a wide range within the EU from 44.3 in France to 8.4 in Portugal (COCIR 2021). As there is no market data in the US, VEIC assumed the density of X-ray machines within California is slightly higher than the EU average at 30 X-ray machines per one million inhabitants.

[14] The energy savings measures for PET scanners are likely similar to the other MIE studied. The project team determined the energy savings range for MRI and CT scanners to be 21.8 percent (COCIR 2018, NREL 2023) to 48 percent (COCIR 2014) per device. However, this is highly dependent on the use profile of the device and the effectiveness of the power management strategy.

In 2023, there was an estimated 658,000 residential electronic air purifiers in the state of California (TechSci Research 2019). As shown in the figure below, the majority of these units are portable air purifiers, accounting for 78 percent of the market share.

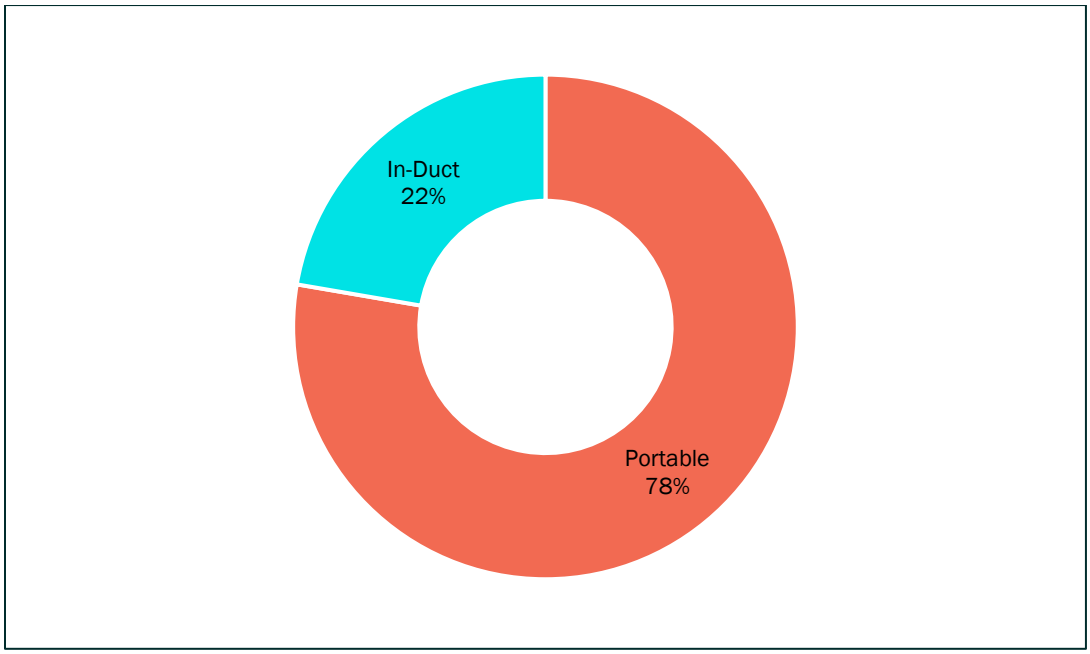

Figure 3: California electronic air cleaning units market share by volume.

Source: (TechSci Research 2019).

The market for air purifiers has seen significant growth in recent years likely due to societal concerns regarding air pollution, climate change, and an increase in wildfires. The market for air purifiers is estimated to be growing at 6.5 percent compound annual growth rate (CAGR) (TechSci Research 2019). To estimate the number of portable electronic air purifiers currently in the state of California, the project team applied the 6.5 percent growth rate to the 78 percent of residential air purifiers estimated in the state in 2017. The team then extrapolated the market share (93 percent) of air purifiers listed on ENERGY STAR's qualified products list of air cleaners to get an estimated 475,781 portable air purifiers in the state of California.

In terms of quantifying the energy impacts and savings potential for air purifiers, their operation and power draw is well documented. The code of federal regulations establishes a baseline for operating efficiency and ENERGY STAR product specifications delineates an efficient option, above code baseline, for air purifiers. Using prescriptive calculations from the California eTRM, annual energy savings per unit are estimated to range, by equipment size, from 10.5 to 116.5 kWh, as shown in Table 11.

This savings estimate varies depending on jurisdiction, reference source, interactive effects, and load profile of the air purifier. Comparably, the 2023 California Energy Efficiency Potentials and

Goals Study[15] estimated 230 kWh in energy savings per air purifier (GuideHouse 2023). Or, selecting savings estimates from a peer group jurisdiction, the Illinois TRM provides annual energy savings estimates between 133 and 790 kWh per device, depending on equipment size and installation parameters (Illinois Commerce Commission 2023).

Air cleaners are estimated to be in operation, or active mode, for 3,641 hours per year (California eTRM 2024). Air cleaners are also estimated to be in idle mode for an additional 3,787 hours per year; meaning they are drawing power for 7,428 hours annually (EMI Consulting 2016).

Table 11: Air Cleaner Operational Conditions

Parameter	Air Cleaner Fan Speed Setting		
	Low	Medium	High
Power Draw as Percent of Power Draw at Full Speed	59%	63%	100%

Source: (eTRM: CA Energy Efficiency Measure Data 2024)

Leveraging the savings characterization detailed in the California eTRM, the project team calculated the energy savings associated with the purchase of a high-efficiency ENERGY STAR qualified air cleaner. The California eTRM follows the federal standards and ENERGY STAR program requirements in terms of delineating equipment efficiency and savings based on the CADR. Using the baseline annual energy consumption per device across CADR classifications, the project team calculated a weighted average of 216.4 kWh per device. With an estimated 475,781 devices in California, the team estimates a total market baseline annual energy consumption of 103 GWh. Similarly, the team estimated the annual energy savings per device of 82 kWh by calculating a weighted averaged across CADR classifications.

[15]. The purpose and function of a potential study is to provide guidance for planning purposes for utilities' energy-efficiency portfolios. It allows for strategic program benchmarking, energy procurement planning, and other cumulative impacts of intervention strategies.

Table 12: Air Cleaner Annual Energy Savings Characteristics

Product Description	Baseline			Efficient			Annual Energy Savings per Device (kWh)
	Avg. Power Draw (Idle Mode) W	Avg. Power Draw (Active Mode) W	Annual Energy Consumption per Device (kWh)	Avg. Power Draw (Idle Mode) W	Avg. Power Draw (Active Mode) W	Annual Energy Consumption per Device (kWh)	
10 ≤ CADR < 100	0.70	32.0	83.2	0.47	28.1	72.6	10.5
100 ≤ CADR < 150	0.70	60.1	154.1	0.54	42.6	109.5	44.6
CADR ≥ 150	0.70	109.3	278.1	0.56	63.3	161.6	116.5

Source: VEIC Analysis and California eTRM

The current penetration of ENERGY STAR products in the air purifier market is assumed to be seven percent (GuideHouse 2023).[16] Extrapolating this across the entire market of air purifiers in California equates to approximately 36,000 ENERGY STAR rated portable electronic air purifiers currently in use. Given the annual energy savings per device, the efficient device saturation in the market, and the total market baseline energy consumption, the team estimates an overall annual market savings potential of 36.3 GWh.

As shown in Figure 4, there are 567 qualified products listed that meet the ENERGY STAR minimum qualifying specifications. These products are $14 to $363 more expensive in cost, depending on the make, model, and equipment size (California eTRM 2024).[17]

[16] 2023 California Energy Efficiency Potentials and Goals Study, CPUC, June 2023, Guidehouse.

[17] California eTRM – Room Air Cleaner, Residential (SWAP008-03), January 2024.

Figure 4: Count of ENERGY STAR qualified products on the market.

Source: ENERGY STAR Qualified Products List, as accessed on April 2, 2024

AIR IONIZERS

A subset of the air purifier market, air ionizers have an added benefit in that they sanitize viral and bacterial pathogens through emittance of negative ions. Their operation and use is very similar to portable electronic air purifiers. The code of federal regulations and energy-efficiency appliance standards for air cleaners includes air ionizers in the specifications. Specifically, it mentions products that utilize ultraviolet (UV) and ion generation, ionic plates and brushes, and ionic filters.

As part of the codes and standards compliance procedures, DOE publishes a Technical Support Document (TSD), which is a wide-ranging product analysis of test procedures, market assessments, and equipment rules and regulations. In DOE's testing and teardown analysis for air purifiers, they showed that air cleaning technology, particularly air ionizers, did not significantly impact the measured energy use or efficiency, meaning the function and energy consumption of air ionizers is comparable to all other air purifiers.

As the established baseline is deemed identical to air purifiers, VEIC reviewed the ENERGY STAR qualified products list to determine if there is a significant difference in the efficient operating parameters between air purifiers and air ionizers.

The ENERGY STAR air cleaner qualified products list includes information on the CADR under different testing standards, including duct, smoke, and pollen. Also included is each unit's efficiency, power draw, and estimated annual energy use. Within every significant operating parameter, air ionizers are within five percent deviation from all other listed air purifiers, as show in Table 13.

Through analysis of available, highly-efficient air purifier options, it is deemed that the savings impact is comparable between air ionizers and air purifiers at 82 kWh annual energy savings per device. DOE and ENERGY STAR regularly group the two products together. Extrapolating the market share of air ionizers listed on ENERGY STAR's qualified products list, it is assumed that the total

market of air ionizers in the state of California is seven percent or 36,000 portable electronic air ionizers currently in use. Given the average annual energy consumption (278 kWh) and savings potential (82 kWh), the estimated equipment stock within the state, and efficient equipment saturation in the market, the project team estimates an overall market savings potential of 2.7 GWh per year.

Table 13: Air Ionizer and Air Purifier Annual Energy Savings Characteristics

Rating	Air Ionizers	Air Purifiers
ENERGY STAR QPL - Count	39	528
ENERGY STAR QPL - %	7%	93%
Dust-Free Clean Air Delivery Rate (cfm)	202.4	205.1
Smoke-Free Clean Air Delivery Rate (cfm)	203.4	198.7
Pollen-Free Clean Air Delivery Rate (cfm)	208.7	217.9
Dust-Free Clean Air Delivery Rate per Watt	4.8	4.6
Smoke-Free Clean Air Delivery Rate per Watt	4.9	4.4
Pollen-Free Clean Air Delivery Rate per Watt	4.9	5.0
Partial On Mode Power (Watts)	0.4	0.6
CADR	204.8	207.2
Power Draw (W)	42.2	44.4
Average Annual Energy Consumption (kWh)	286.1	278.5
Average Annual Energy Savings (kWh)[18]	74.4	81.9

Source: ENERGY STAR Qualified Products List, as accessed on April 2, 2024, and VEIC Analysis

POSITIVE AIRWAY PRESSURE MACHINES

CPAP plug loads have not been widely studied, but based on their use, which is fairly static, a number of operating parameters and performance characteristics can be estimated.

The primary energy consuming component of a CPAP machine is the motor. Attached to a pump, the motor pressurizes and circulates air through the CPAP attachments and into the user's lungs. The motor is designed to operate quietly and not interrupt sleep.

An optional component that some CPAP machines include is a humidifier and/or heater. The humidifier increases the moisture of the air delivered to the user, as CPAP machines can cause xerostomia, commonly referred to as dry mouth.

Based on a review of product literature, CPAP ventilators have a relatively small power draw, ranging from ten to 100 watts (Rainer, Meier and Hosbach 2021). Because of the lower power requirements, CPAP machines can operate effectively from most household outlets and have battery backups that can provide enough power for two continuous nights of use. The estimate in terms of annual energy

[18] Energy savings are derived using the California eTRM methodology.

consumption ranges from 77 kWh per year (Rainer, Meier and Hosbach 2021) from one study to 30 to 300 kWh per year, with an average of 156 kWh per year (Meier, et al. 2020) from another. Units with humidification and heaters typically fall in the higher range for energy consumption.

National and statewide equipment stock data are not available for CPAP machines, making their market share difficult to quantify. LBNL estimated 2.2 million CPAP machines in use nationally, based on a combination of factors derived from Americans inflicted with sleep apnea. Adopting a similar methodology, the following stock and energy consumption data are estimated for California.

Table 14: Stock and Energy Consumption of CPAPs in California

Device	Existing Equipment Stock	Annual Equipment Sales	Annual Energy Consumption per Device (kWh)	Stock Energy Consumption per Year (GWh)
CPAP	300,000	53,000	77 - 155 kWh	23.1 - 46.5 MWh

Source: LBNL

The project team was unable to identify any energy savings measures or standards for efficient CPAP technology through review of existing literature and stakeholder engagement.

VENTILATORS

Ventilators are considered a durable medical device, ordered by a healthcare provider for routine, long-term use. Ventilators are one example of durable medical equipment that requires a reliable, uninterruptible power supply in order to function properly and sustain life.

One study the project team reviewed conducted by the HHS and CDC looked at the effects of power outages on vulnerable populations dependent on electrically powered medical equipment (Molinar, et al. 2017). The study relied heavily on the Truven Health Market Scan database,[19] which provides information on the inpatient and outpatient claims of employer-sponsored privately insured enrollees. Through review of this database, and extrapolation across the entire population, there are an estimated 685,000 electrically dependent persons residing at home nationwide (Truven Health Analytics). Using the same methodology for the state of California, the project team estimates 63,800 electrically dependent persons residing in the state.

Residents relying on ventilators were an integral part of this research, as these devices can be operated using batteries, but only for a limited time. Battery life can span two to four hours, and with extended external battery packs, device operation can be extended for another 12 hours, making reliable power crucial to their use (Molinar, et al. 2017).

In the study's review of durable medical device claims, it was determined that 3,143 were for at-home ventilators nationwide. Comparably, for California, there are approximately 300 ventilators in use in residential settings.

[19] The databases are a collation of administrative claims that contain data on impatient and outpatient claims, outpatient prescriptive claims, clinical utilization records, and healthcare expenditures.

The project team was unable to identify any power consumption, energy savings measures, or standards for efficient ventilator technology through review of existing literature and stakeholder engagement.

RESIDENTIAL DEVICE SUMMARY

Of the devices studied in this report, the market and technical characterization of air cleaners is by far the most mature. The project team found limited information to characterize the energy consumption and savings potential for CPAP machines, ventilators, heating pads, dialysis machines, and infusion pumps. While information to estimate the energy consumption of CPAPs exists, little to no information was found on existing or planned savings measures for these device types. While information on the average energy consumption per device of infusion pumps and dialysis machines in residential settings may be similar to those studied in hospital and healthcare facility settings, the project team did not find existing information on the market size in the state of California. The project team investigated requirements and cost of accessing the Truven Health MarketScan data and other commercial medical databases, in hopes of estimating the number of at-home dialysis machines and infusion pumps in the state following the steps outlined by (Molinar, et al. 2017). The team found that the requirements and cost to access this data were outside the scope of this project but may prove valuable for future research and should be evaluated further.

Limited research on heating pads exists; the literature reviewed studied the use of custom heating pads as personal comfort systems to reduce heating and cooling loads in buildings. The market is fragmented with a large number of manufacturers. The use of heating pads for heat therapy is incredibly variable and challenging to quantify. Furthermore, heating pads are explicitly excluded from the qualifying medical devices of a few California IOU MBA programs.

Table 15: Summary of Residential Medical Device Findings

Device Type	California Equipment Stock	Total Market Baseline Annual Energy Consumption, GWh	Overall Annual Market Savings Potential, GWh[20]
Air Purifiers	475,781 devices	103.0 GWh	36.3 GWh
Air Ionizers	35,143 devices	7.6 GWh	2.7 GWh
PAP Machines	300,000 devices	46.5 GWh	0
Ventilators	293 devices	Unknown	0
Infusion Pumps	Unknown	Unknown	0

[20] For devices where energy savings potential is indicated as "0," the project team could not establish any energy savings potential, either through power management or energy efficiency.

Device Type	California Equipment Stock	Total Market Baseline Annual Energy Consumption, GWh	Overall Annual Market Savings Potential, GWh[20]
Dialysis Machines	Unknown	Unknown	0

Source: Project Team

Recommendations

Based on findings from the literature review and stakeholder engagement, the project team has identified existing mechanisms for achieving higher medical device energy efficiency and recommendations for achieving greater efficiency and energy savings in the California market.

Mechanisms for Achieving Higher Efficiency

Currently, the primary mechanism for achieving greater energy efficiency of medical devices is through power management: turning devices off or into low power modes, either manually or automatically, when the device is not in use. For existing devices, particularly devices with manually triggered low power modes, user behavior can play a major role in energy consumption of individual devices. Healthcare sustainability teams and radiology departments should develop departmental protocols and educational programing to increase general awareness around medical device energy consumption and means for increasing energy savings. When possible, procurement teams should prioritize devices with automatically triggered low power mode capabilities.

Barriers and Opportunities for Greater Efficiency and Energy Savings in California

Create a metering guideline: A guideline for metering MIE at healthcare facilities can serve as a helpful resource and may reduce barriers for research teams or internal hospital staff looking to monitor the energy consumption of MIE and other medical equipment. This guideline should include information on key stakeholders to involve in the process, standard data collection protocols (including detailed data collection methods that do not provide opportunities for data to be breached), and specific considerations for developing a metering plan. The intended audience of this guide should be facilities managers or researchers looking to understand the energy consumption of medical devices. It is important to ensure accessibility of this resource by providing information that is digestible for a multitude of stakeholders.

Conduct further research and collect data: Without an understanding of baseline or current energy consumption, the energy savings potential cannot be estimated without large uncertainties. Further research and data are needed to characterize the market for residential or durable medical devices found in home-health settings. Access to databases such as Merative, formerly Truven Health, MarketScan, and other commercial datasets that include insurance claim information may provide the data necessary to quantify the number of devices within California. Access to these databases is

costly, and detailed information about what these databases include can be challenging and time consuming to track down. Additional research and metering is needed to characterize the usage and load profiles of ventilators, infusion pumps, and dialysis machines in order to quantify the energy consumption and savings potential of these devices. In general, there has been more research and data collected on larger MIE however, much of the data comes from European sources, like COCIR. Further research, including metering of MIE, to capture load profiles of different facility types and use cases within the US will strengthen energy consumption and savings estimates.

Build out and maintain a live database of power management instructions: Information on power management of medical devices, particularly large MIE, can be challenging to locate and access. End users often don't have time or capacity to search this information out. Multiple stakeholders expressed interest and support in the development of a live database to house device power management instructions. Future work should include identifying an authority responsible for hosting and maintaining the database and compiling and building out the database itself. Ideally, in the future, manufacturers could report information on their devices for inclusion in the database.

Use forthcoming ENERGY STAR specification to develop incentive programs: Currently, there are no medical device measures incentivized within the state of California, with the exception of energy-efficient air cleaners. Without adequate data or information or relevant standards and guidelines, energy-efficiency program administrators and implementers cannot build programs to support medical device measures. The forthcoming ENERGY STAR specification for MRI machines presents the first opportunity for program administrators and implementers. Furthermore, sustainability and procurement teams should develop procurement policies around the forthcoming ENERGY STAR specification and advocate for the expansion of this ENERGY STAR certification to all large imaging equipment.

Require manufacturers to report energy consumption of medical devices: There are currently no standards or guidelines for the energy consumption of medical devices studied in this market characterization, with the exception of air purifiers and ionizers. This is in part due to the exception in the CFR and Title 20 of California's Code of Regulations that exempts medical equipment from regulations. Because of this, manufacturers of medical devices have no incentive within the US market to improve the energy efficiency of their devices, or even report out on the energy characteristics of their devices. While pressure from end users and sustainability advocates within the healthcare space will drive improvements in the energy efficiency of devices, this often takes time and momentum. Manufacturers should be required to report this information even if they are not held to any standards.

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Appendix A: Reference Table of Device Power Management

See Final Report Supplement Appendix A: Reference Table of Device Power Management for more details

NOTE: Refer to the operator manual for information on when to shut off equipment.											
Device Manufacturer	**Medical Device Category**	**Medical Device Model Name**	**Power Reduction Capability**	**Automatic v. Manual Transition**	**Time to go from a Lower Power Mode to Active Mode**	**Power Reduction Guidance**	**Section Reference to Guidance**	**Page Reference (transition to low power mode)**	**Page Reference (transition to active mode)**	**Document Title**	**Publication Date**	**Link**
Siemens	CT Scanner	SOMAOM go	System Shutdown	Manual	Unknown	The gantry and the console workplace are running. You can shut down the system by using one of the following keys: The On/Off key in the gantry connector box located in the gantry stand. The wall switch OFF key if a wall switch is installed. The line connection box (LCB) power switch if an LCB is installed. You are informed about the system shutdown with a timer dialog. You can cancel shutdown by pressing one of the keys mentioned above a second time. If the shutdown is confirmed, the system continues to finish all the jobs and shuts down afterwards	Chapter 11	66	68	SOMATOM go. Quick Guide - SOMATOM go.All syngo CT VB10	Nov-23	SOMATOM go. Quick Guide – SOMATOM go.All (siemens-healthineers.com)
Phillips	CT Scanner	Spectral CT	System Shutdown	Manual	Unknown	First, shut down the gantry and host. 1. Shut down the gantry and host: – On the scan control box, turn the key to OFF. – Click Log out. Follow the screen prompts. – Click Shutdown. – Click OK. The host will turn off. 2. Shut down the CIRS computer(s): – Locate the CIRS computer(s) inside the cabinet. – Press and hold the Power button for 2 seconds and release. – Wait 2-3 minutes for the CIRS to power off. If the computer still has not shutdown, press the power button briefly two times and release. – If after another 2-3 minutes the computer has not shutdown, press and hold the power button down to force the computer off. – Follow the same steps for all CIRS servers. 3. Switch off Console Uninterruptible Power Supply (UPS), if applicable. – On the Power Distribution Unit (PDU), move the main switch to the OFF position. – Wait 2-3 minutes and then move the main switch back to the ON position (and press the green Start button if required) to restore power to the gantry. Note: When removing power from gantry for an extended amount of time, wait 30 minutes before generating x-rays after Restart	Chapter 5	177	177	Spectral CT - Version 5.0 - Instructions for Use, English, 300011294651_A	Jun-23	300011294651_A_spectral_ct_ifu_en-us (philips.com)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
Baxter	Dialysis Machine	2008T Hemodialysis Machine	Low Power Mode Capability	Automatic	Unknown	This option is used to set the time the 2008T hemodialysis machine will remain idle on the "Select Program" screen before entering Low Power Mode. The available selections are: OFF (in which the machine does not enter Low Power Mode), 5, 10, 15, 20, 25, and 30 minutes. In Low Power Mode, the machine's hydraulics (pumps and valves), modules, and display screen turn off and the hour meter stops incrementing; the Status Light will flash green and the CDZ system will remain on. The machine will 'wale up' to full power mode when the keyboard, touchscreen, or touchpad are touched. The 'Time to Low Power Mode' option is part of 2008T BlueStar Premium and requires additional hardware.	Chapter 1	30	341	Introduction to the AK 98 dialysis system, V2	Apr-20	2_SW2.XX_AK 98 Dialysis Machine Introduction_User_EUMP_MG208_15-0002a(1) (1).pdf
Baxter	Dialysis Machine	Artis Physio Plus	Low Power Mode Capability	Manual or Schedule Option	Unknown	The Hard Key panel On/Off key is lit (green) - The Main Switch On indicator is not lit • Press the On/Off key on the hard key panel to “wake up” the machine • The machine will boot-up and load the software before it enables the start of preparation		54	54	How to use the Artis Physio Plus (SP01745 SW 9.05)		The Artis Physio Plus system manual (baxter.com)
Baxter	Infusion Pump	Sigma Spectrum Infusion Pump	Low Power Mode Capability	Manual	Unknown	AC Sleep Mode occurs when a Wireless Battery Module is installed in the Pump, the Pump is powered off and AC power is connected. While in AC Sleep Mode, the Pump will: Charge the battery (if a wireless battery module is installed), Periodically connect to the network at the configured time interval to check for, and download if applicable, a new Drug Library. Interval times are configured in the MDL (Master Drug Library software) as 1 hr, 6 hr and 24 hr. For details, refer to the SIGMA Spectrum Infusion System Master Drug Library User Manual, Report its location, if configured to do so in the MDL. NOTE: If using a Wireless Battery Module and networking is off, only battery charging occurs. NOTE: If using a Standard Battery Module, only battery charging occurs	Design and Theory of Operation	145	27	Service Manual: Sigma Spectrum Infusion Pump with Master Drug Library	Jul-18	Sigma_Spectrum_Service_Manual.book (cloudinary.com)
B. Braun	Infusion Pump	Infusomat	System Shutdown	Manual	Unknown	Press fs to stop the infusion. The green LED goes out. Close the roller clamp and disconnect the line from the patient. Remove emergency aperture cover. Turn crank inside aperture to open the door. Turn crank to remove emergency aperture cover. 42 Chapter 1 • Press x and open the pump door with u and remove IV line per above in Section 1.12. • Close door and press o for 3 sec to power off the pump. Note: When pump is powered up user will be prompted to continue last infusion, answering No returns to B. Braun landing page. Note: Pump cannot be powered off with IV line inserted.	Chapter 1	41	18	Infusomat Space & Accessories		38911794J_ISP_GB_0410_qxp5_Entwurf.qxd (shopify.com)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
Alaris	Infusion Pump	Alaris 8015	System Shutdown	Manual	Unknown	Press and hold CHANNEL OFF key until a beep is heard (approximately 1.5 seconds) and then release to initiate power down. • During power off sequence, Main Display flashes Powering Down. • To interrupt power down sequence, quickly press any key (except SYSTEM ON) on PC unit. Once all attached modules are powered off, PC unit automatically powers down.	Chapter 1	25	19	User Manual - Alaris System with Guardrails Suite MX	Dec-16	Alaris System User Manual v9.19 (shopify.com)
GE	MRI	Signa 7T	Low Power Mode Capability	Manual	40 minutes	1. Make sure all images have reconstructed and are available for display from the Patient List. 2. End an exam, if necessary. 3. Wait for all post processing, archive, network, filming, CD/DVD, etc. functions to complete. 4. Remove any archive media, if necessary. 5. From the header area of the screen, click the Tools icon arrow and select System Shutdown. 6. When prompted, click on the reason for the system shutdown: Daily, Service, Other or Cancel to exit the shutdown of your system. The application begins to shut down, which can take less than 15 minutes. When the shut down is completed, the screen goes blank and the computer turns off. 7. To power on the system, see System startup procedure.	Chapter 3	306	295	Signa 7.0T 29.1 Operator Manual	Dec-23	Manuals | GE HealthCare (United States)
Siemens	MRI	Magnetom Cima.X	Low Power Mode Capability	Manual	Unknown	If you do not intend to perform measurements for a longer period of time or only want to edit or evaluate images, you can save energy by enabling the Standby mode. In this mode, the MARS (measurement and reconstruction system) shuts down and the power saving mode of the MR cooling system turns on. You cannot perform measurements in Standby mode. ✓ The Home Screen is open. 1 To start Standby, click the Shutdown icon and select Scanner Standby. In the Standby System dialog box, click Standby. The MR scanner switches to the low power Standby mode. 2 To end Standby, press the SYSTEM ON button on the alarm box.	Chapter 5	134	134	Magnetom Family Operator Manual - MR System and Coils syngo MRXA61	Mar-24	MAGNETOM Family Operator Manual – MR System and Coils (siemens-healthineers.com)
Phillips	MRI	Ingenia, Ingenia S, Ingenia Evolution	Low Power Mode Capability	Automatic	Unknown	Powering and system startup must be performed by a Philips service engineer. This includes final adjustments of hardware compensation and control settings. Under normal circumstances it is not possible to switch off the system completely or partly. When not in use the system will switch into standby mode after approximately two hours of inactivity. Power consumption is then minimized.	Chapter 12	879	879	Ingenia, Ingenis S, Ingenia Evolution - Instructions for Use, English, Rlease 10, USA Version (3000 062 80121/782* 2021-02)	Feb-21	300006280121_ifu_p7i_us_pnl_ce_en-US_2021-02 (philips.com)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
GE	PET Scanner	Discovery 710	Low Power Mode Capability	Manual	Unknown	1. Click Shutdown on the right display monitor to open a window similar to the ones shown in the following illustrations. 2. Select Energy Saving Mode and click OK. 3. On the Energy Saving Mode window, set the desired startup date and time. The day can be adjusted by clicking on the up and down arrows. The hour can be adjusted by clicking on the up and down arrows. The minutes can be adjusted in 15-minute intervals by clicking on the up and down arrows. The system startup date and time cannot be less than seven hours after the current date and time. NOTE: You can set up the schedule for Energy Saving Mode. This allows you to set the desired startup time for multiple days at once. The Energy Saving Mode still needs to be initiated manually each day. Click Schedule. Refer to Figure 113 on page 187. Select the desired days. Set the desired startup time. Click Accept. Note that the startup date and time will change to the next day and time per the schedule. If needed, set the startup date and time. Note that this can be customized for the next startup without affecting the schedule. 4. Click OK to initiate Energy Save Mode. 5. An Attention window will display when the Energy Saving Mode setup has completed. Click Confirm to initiate the shutdown. When the system successfully completes the shutdown process, it displays the message “System Halted.” 6. Push the console power button to turn off the power. 7. To restore power, push the power button on the console. The console will not automatically turn on	Chapter 6	185	179	Discovery MI Digital Ready, Dicovery 710 and Discovery 710 Clarity User Manual	Jan-21	Manuals | GE HealthCare (United States)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
Siemens	PET Scanner	Biograph mMR	Low Power Mode Capability	Manual	Unknown	Starting/ending Host Standby D.3 Host Standby can be started from System On as well as System Off. From Host Standby you can switch the system to System On or switch it off completely. You can also use the syngo System Manager to switch between Host Standby and System On. - Starting Host Standby from System Off, The system is in the System Off operating status, Turn the keyswitch at the alarm box to the right. The system is unlocked. Press SYSTEM STANDBY. The host computer and the PET computer is booting up. - Starting Host Standby from System On, The system is in the System On operating status. Press SYSTEM STANDBY at the alarm box. All components except for the host computer are switched off. The SYSTEM ON LED goes off. D.3 - Starting up and shutting down the system operation, Ending Host Standby Ending Host Standby and switch to System On, The system is in the Host Standby operating status. Press SYSTEM ON at the alarm box. The measurement-related components of the system are started. The SYSTEM ON LED lights up. Ending Host Standby and switch off the system. The computer system has been shut down. Press SYSTEM OFF at the alarm box. The system is switched off. Turn the key switch at the alarm box to the left. The system is locked	Chapter D.3	159	160	Biograph mMR 0.0 Operator Manual - MR-PET System 0.0 syngo MR B18P	Jul-11	MR-PET System (siemens-healthineers.com)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
Phillips	PET Scanner	Vereos Digital PET/CT	System Shutdown	Manual	Unknown	Click the Tool icon. Click Shutdown All. The Power Control Application window opens. From this window, you have the option to select: – Full System Shutdown — This option shuts down the computers, the chiller, PET ring modules, and the PET Power and Cooling Control Unit (PCCU) on the system. When you start the system up again after selecting Full System Shutdown, you must perform Daily PET QC to resume scanning operations. – Servers Restart — This option shuts down and restarts the computers on the system, but does not shut down the chiller, the PET ring modules, or the PCCU. When the system restarts after selecting Servers Restart, you do not have to perform Daily PET QC to resume scanning operations if it has already been performed that day. 3. From the Power Control Application window, select Full System Shutdown. 4. At the bottom of the window, click Start System Shutdown to begin the process. The Power Control Application window displays a list of each component and its status as shutdown proceeds. The following components are shut down: – Data-M – PET Recon – PET Acq – PCCU – CT Recon System Startup and Shutdown Shutdown All (Weekly) Wait as the system shuts down the components in sequence. The following symbols are displayed next to each component as the shutdown proceeds. – — Complete – — Waiting or In Process – – — Error The Console computer is the last component to shut down. NOTICE If the Error symbol appears next to a component in the list that is shutting down, the shutdown did not occur for that component. If this occurs, note the error and contact a Philips service representative. Restarting the System after selecting Full System Shutdown Use this procedure to turn on the system when the Full System Shutdown option was selected. Before turning on the system, verify all phantoms and phantom holders are removed from the patient table. 1. Press the power switch on the front of the Console computer. 2. At the Login window, type your username and press Enter. The default username is pet. 3. Click Yes to accept the License Agreement. Typically, the system requires three to five minutes for the computers to turn on. Allow 10 minutes for the startup and connection to complete before initiating troubleshooting procedures. 4. Click the Tool icon to check the PET and CT status indicators.	Chapter 3	49	50	Vereos PET/CT System - Reference Manual English - 459800505023_C	Mar-20	Vereos Reference Manual 459800505023_C (philips.com)

Device Manufacturer	Medical Device Category	Medical Device Model Name	Power Reduction Capability	Automatic v. Manual Transition	Time to go from a Lower Power Mode to Active Mode	Power Reduction Guidance	Section Reference to Guidance	Page Reference (transition to low power mode)	Page Reference (transition to active mode)	Document Title	Publication Date	Link
GE	X-Ray	Definium Tempo Pro	Low Power Mode Capability	Manual	Unknown	1. Close all open exams. 2. Click the Utilities button at the top of the Worklist screen. 3. Select System on the Utilities screen. 4. Click [SHUTDOWN]. Note: Allow for the tube fan speed to slow (if running high) before proceeding. 5. Click [YES] to proceed with shut down, or [CANCEL] to return to the Utilities screen. Note: Wait approximately 30 seconds after a shutdown to power up the system. Note: Systems with an Uninterruptable Power Supply (UPS) For proper system and UPS integration to occur, you must wait one minute before power to the system is restored. If not, you must press the power button on the RCIM and then the computer power switch to successfully link both the system and UPS. *One minute is the default UPS power cycle. Note: Power Off - Systems with an Uninterruptable Power Supply (UPS) When performing a shutdown, the GE Healthcare X-ray system, desktop computer and monitor will power down. The UPS will display “Battery Mode - Load Protected” and an orange status indicator light will be visible. The UPS will sense that the computer and monitor are powered down (kW and kVa will be at 0.0). After one minute of the system being off, the UPS will have no indicator lights displayed and will display “Press to Start - Load Not Powered.” Once a user is ready to Power On the system using the GE Healthcare RCIM, both the X-ray system and UPS will power up together. See Power button on RCIM2	Chapter 4	88	88	Definium Tempo Pro/ Definium Tempo Digital Radiographic System Operator Manual	Oct-23	Manuals | GE HealthCare (United States)
Siemens	X-Ray	Luminos Agile Max VF11	System Shutdown	Manual	Unknown	Press the button on the control room module. Refer to the FLUOROSPOT Compact Operator Manual for further information. The entire system and all further connected devices are immediately switched off. All started operating sequences will be interrupted and the selected programs will be deselected. If a background job is running (for example, transfer to CD), the imaging system will not shut down until the job is finished. If it is necessary to stop the imaging system immediately, the background job must be ended first	Chapter 4	100	101	Luminos Agile Max Operator Manual - VF11 and higher	Apr-23	Luminos Agile Max Operator Manual – VF11 and higher (siemens-healthineers.com)
Phillips	X-Ray	Digital Diagnost C90	System Shutdown	Manual	Unknown	The Eleva Workspot is designed for continuous operation. Therefore, it is necessary to switch off all components only in the event of prolonged stoppages. It is recommended to restart the Eleva Workspot and all other components once a week. *see operational manual for images of the buttons to press* Press this monitor button to switch off the Eleva Workspot and all other components.NOTICE It can take several seconds for the system to shut down. NOTICE Do not keep the button pressed. If you keep the button pressed for more than 4 seconds, the system is aborted. This might harm the system. Aborting the System -The system is not responding and cannot be shut down properly. -Press this monitor button for approx. 4 s. -The Eleva Workspot and all other components shut down. NOTICE Abort the system only if necessary. It might harm the system. Restarting the System -Press this for 4 s. -The Eleva Workspot is restarted. All other components are not affected by the restart.	Chapter 4	94	95	Digital Diagnost C90 Version 1.1 - Instructions for Use, English	Mar-23	451298746122aa IFU Digital C90 V.1.1 EN (philips.com)