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How Sustainable is my ULT Freezer?

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Executive Summary

Sustainability has a growing importance in the scientific community. Besides the well-known containers with biological, chemical, or radioactive waste, energy-guzzling ULT freezers in use 24/7 are high on the list of concerns. The sustainability of a -80 °C ULT freezer is not limited to energy consumption. The sustainability footprint of a product like this is a multi-factor story, including aspects related to development, production, logistics, usage in the laboratory, maintenance, and finally disposal. The focus of this White Paper is on the usage of ULT freezers in the laboratory and related sustainability aspects.

Introduction

In a broad sense, the concept of sustainability refers to the ability to maintain a process at a certain rate or level over time. While this concept can have economic and social dimensions, the most well-known aspect is environmental sustainability. In our private lives this may include recycling of paper and plastics, or conservative use of energy and water to reduce our impact on natural resources. Increasingly, these practices have been making their way into the lab. Compared to a few years ago, talking about lab equipment is no longer limited to performance and price. The topic of sustainability and the overall impact of a product play an increasing role in the decision-making process. Scientists, technicians, students, sustainability officers but also purchasing departments and procurement systems request information. At Eppendorf, we see a growing interest in our company's commitments and our approach to sustainability for all our products. This interest is split into two subtopics:

> What is Eppendorf as a production facility/ supplier doing to improve the sustainability of its freezers?
> What can I do as a user in the lab to improve the sustainability footprint of my ULT freezer?

Progress and continuous improvements in respect to sustainability require open communication about performance of products and testing measures. In parallel, there are official third-party certification processes like the quality and environmental management standards ISO 9001 and ISO 14001 for the Eppendorf Group as well as ACT® and ENERGY STAR® certifications specific for ULT freezers.
In this White Paper, we focus on the second question: What can I do as a user in the lab to improve the sustainability footprint of my ULT freezer in the lab? The first question is addressed in a separate White Paper.

Though a detailed life cycle analysis based on Scope 3 (Scope 3 emissions describe greenhouse gas emissions along a company's value chain) is still challenging, there are certain elements that can be examined in the life cycle of a freezer, especially its life after the unit has been shipped to the laboratory. These include the aspects of installation, temperature set-points, maintenance, sample management, etc.

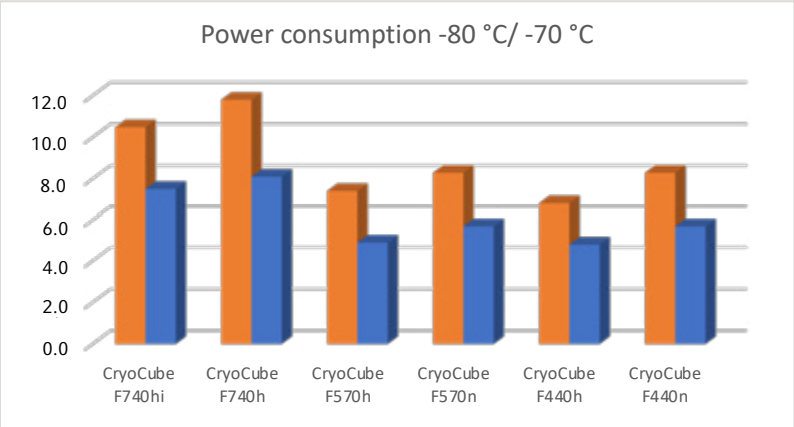

Figure 1: Average energy savings in kWh/ day when changing the set-point of an Eppendorf ULT freezer from -80 °C to -70 °C. The data are based on Eppendorf-external tests with 3 empty units (230 V) in parallel and 20 °C room temperature.

When it comes to the sustainability of ULT freezers, energy consumption has always been the primary concern, followed by the environmental impact of the refrigerants used. Since these freezers must maintain ultra-low temperatures 24/7, a lack of energy efficiency can have a big impact on the amount of energy consumed and on your electric bill. Cooling liquids also play an important role, as different types of refrigerants have different ozone depleting potential (ODP) and global warming potential (GWP). Since Eppendorf launched its first freezer using hydrocarbon coolants in 2008, many modern ULT freezers now utilize these more eco-friendly refrigerants.
In addition to energy consumption and cooling, there are many other aspects that play a role in the overall sustainability of the ULT freezer. These include everything from the proper installation of the freezer to regular maintenance to its ultimate end of life.

Independent certification
The environmental impact of a product can be stated by the supplier, but for another objective analysis of many of our ULT freezers, Eppendorf also utilizes independent 3rd party organizations to validate our instruments. We cooperate with the ACT® concept of My Green Lab® as well as energy testing by ENERGY STAR. Details are listed on the Eppendorf web pages for these products. Keep in mind that ENERGY STAR data are based on 115 V versions and a different test protocol compared to the test house utilized by Eppendorf (see White Paper 75 for details on both testing procedures).


ACT.
The Environmental Impact Factor Label
US

Eppendorf CryoCube F740hi ULT Freezer
Maldon, United Kingdom

Environmental Impact Scale
Decreasing Environmental Impact
1 — 10

Manufacturing	
Manufacturing Impact Reduction	6.0
Renewable Energy Use	Yes
Responsible Chemical Management	1.0
Shipping Impact	8.4
Product Content	5.0
Packaging Content	1.0
User Impact	
Energy Consumption (kWh/day)	12.3
Water Consumption (gallons/day)	N/A
Product Lifetime	5.0
End of Life	
Packaging	4.2
Product	1.0
Environmental Impact Factor:	**43.9**
Label Valid Through:	June 2022

act.mygreenlab.org

Figure 2: Independent ACT certification by My Green Lab and ENERGY STAR certification provide objective verification

Installation

The instrument should be installed according to the instructions in the Eppendorf operating manual. By definition, this is 150 mm/ 6 in from the back wall and at least 150 mm/ 6 in from lateral objects. The 150 mm are commonly recommended by many suppliers to allow for air movement around the instrument.

Quite often, we see packaging material or supply boxes of consumables stored on top of ULT freezers. This should be avoided to ensure proper air circulation around the instrument. Packaging material blocking air circulation increases the power consumption of the freezer as the compressors need to work harder to maintain ultra-low temperatures. Diminished air circulation may increase the risk of compressor failures due to the constant level of stress on the compressors (overheating). Please also keep in mind the local restrictions in respect with to storage of combustible material in rooms or hallways. Product packaging is mainly made of cardboard. In many labs, the safety officers (in cooperation with the local fire department) limit the amount of cardboard material due to safety concerns.
If possible, freezers should not be installed in long hallways or big labs: Besides the strain of noise for the scientists, the efforts required to control the room temperature increase with the size of the room.
The heat generated by the freezer must actively be removed to avoid overheating of the freezer, which can damage the compressor and ultimately lead to the premature failure of the freezer. As a result, you may face the loss of investment (broken freezer) as well as the irrecoverable loss of thousands of samples. Following manufacturer guidelines is an easy way to extend the lifetime of the instrument.
The lab air flow controlled by ventilation systems reduces the risk of overheating. Many regulations specify a specific air exchange in labs, for example eight times/ hour. This air flow and exchange can be difficult to control in larger lab spaces with more equipment, furniture, and moving people. Where possible and feasible, we recommend to install freezers in dedicated rooms where the air flow can be optimized and constantly controlled. This can reduce the energy usage for air ventilation as well as optimize the storage conditions for samples and freezers.

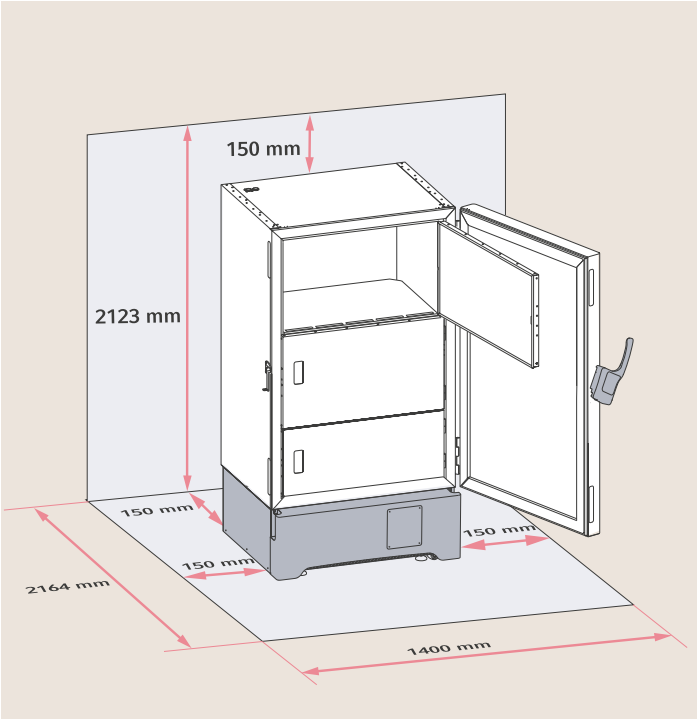

Figure 3: Recommended distances for installation of an Eppendorf ULT freezer

Disposal of packaging material

The packaging of the ULT freezer contains different materials. Besides the percentage of recycled material used for producing a product's packaging, the recycling or reuse of the packaging after its intended use is another important sustainability factor to consider. In Europe, for example, nearly all cardboard material is recycled. Please support the global sustainability initiative of recycling valuable raw material by also collecting the freezer cardboard packaging material and disposing of it in the appropriate collection container at your organization. In respect to the plastic dust cover made of low-density polyethylene (LD-PE) and the foam parts, we recommend to select a dedicated recycling partner where PE material can be recycled. We suggest you contact your local waste hauler or facility management team to understand the available recycling options for your organization.

Heat output & HVAC

Running a freezer generates heat. Besides the described dilution of heat in the room by air ventilation, the room can be temperature-controlled by active cooling (HVAC/ heating, ventilation and air conditioning).

When less heat is generated by the freezer, there is less heat to be removed by the HVAC system. The less the HVAC system has to work, the less energy it consumes.

For new buildings or renovations, a structured freezer concept can even result in a smaller HVAC system which also consumes less electric power. Exact correlations between how much freezer heat release requires what amount of counter cooling is difficult to calculate. One way to calculate the maximum heat output of an instrument is from the daily total power consumption as electric power, which is the only component of the freezer which can be transformed into heat.

For example, CryoCube® F570h (-80 °C and 20 °C room temperature) requires 7.4 kWh per day which is then divided by 24 hours. These 308 Wh (W per hour) can then be transformed into BTU (British Thermal Units). 1,000 BTU/h represent ca. 293 Wh, resulting in a maximum heat load of 1,051 BTU/ h for this freezer.

Although freezers can run at a room temperature of 15 to 32 °C, the recommended room temperature should be around 20 °C as higher external temperatures require more compressor work and finally more power consumption.

The heat output into the lab environment can also be reduced by using water-cooled ULT freezers. Instead of a fan which pushes heat out into the lab, this type of freezer is connected to a cooling water circulation system. Once the cool water removes the heat, the now warmed-up cooling water from the ULT freezer is directed to a heat exchanger which can be part of the central building heating system. This heat exchanger extracts the heat from the freezer cooling water to support the building heating system. When leaving the heat exchanger, the freezer cooling water is cooled down to be re-used at the ULT freezer.

This circulation process saves resources as well as money by supporting the local building heating system. For more information on water-cooled freezers, see White Paper 53.

Energy saving versus temperature accuracy

As a rule of thumb, ULT freezers can be optimized in development in respect to extremely low energy consumption or in respect to temperature accuracy. A very simple way to reduce the energy consumption is a less accurate temperature control. The borders for the acceptable temperature range within the freezer chamber are then broaden up. The breaks between the active cooling phases by the compressors are expanded. As a result, the power consumption is reduced.

At Eppendorf, sample safety is paramount. Power consumption of ULT freezers needs to be minimized but not beyond the point where your samples are put at risk due to suboptimal temperature accuracy and expanded recovery times after door opening.

Important factors that impact energy consumption

When designing a new ULT freezer, many aspects need to be taken into account to optimize energy consumption while providing highly accurate temperature performance.

> Thickness of insulation
> Type of insulation
> Type of cooling liquid
> Efficiency of compressors
> Control of compressors
> Pressure in the cooling system
> Style of cooling loops (diameter, length, density, etc.)
> Seals of outer door
> Seals of inner doors
> Insulation of outer door
> Insulation of inner doors
> Airflow of heated air
> Construction and position of filter
> Sealing of access ports and vent ports

Figure 4: Power measurement of a freezer

Energy consumption
Energy (electric power) is needed to create cold for the thousands of high-value samples within the ULT freezer. Even environmentally-friendly and energy-efficient ULT freezers still consume a significant amount of energy compared to other lab instruments as they must maintain extremely low temperatures 24/7. With today's high energy costs and focus on the environment, energy conservation has become increasingly important in the lab. High-quality, eco-friendly ULT freezers are designed to help you save energy and reduce your carbon footprint without compromising sample safety.

-70 °C instead of -80 °C
For decades, the recommended long-term storage temperature for biological samples has been -80 °C. In recent years, there have been an increasing number of discussions about changing the set-point of the freezers from -80 °C to -70 °C to save energy. So far, there is no clear indication either way that the temperature change does or does not cause harm to samples. For sure, the change of 10 °C should not have an impact on the majority of samples.

At the University of Colorado Boulder, half of the ULT freezers are now running on -70 °C (out of 150 units in total). The local Green Labs Program started with 5 units at -70 °C in 2010 and seems to be successful for certain sample types.

Learn more: https://www.colorado.edu/ecenter/green-labs/lab-energy-efforts/freezers/70-0c-efforts

Figure 5 shows the average energy savings of 2 to 3.5 kWh/ day when changing the set-point from -80 °C to -70 °C on a CryoCube ULT freezer. On average, the change results in a reduction of energy consumption by ca. 30%. The data are based on Eppendorf-external tests with three empty units (230 V) in parallel and 20 °C room temperature.
In figures 6 and 7, the average cost per kWh is defined as 0.21 € (EuroStat 2019), while the greenhouse gas emission calculation is based on www.eea.europa.eu 275 g CO_2/ kWh (2019).

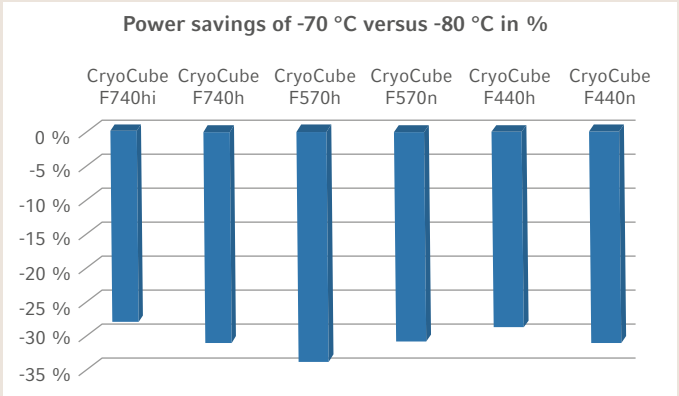

Figure 5: Average energy savings when changing the set-point of -80 °C to -70 °C. On average, the decrease results in a saving of ca. 30% power consumption. The data are based on Eppendorf-external tests with 3 empty units (230 V) of each type in parallel and 20 °C room temperature

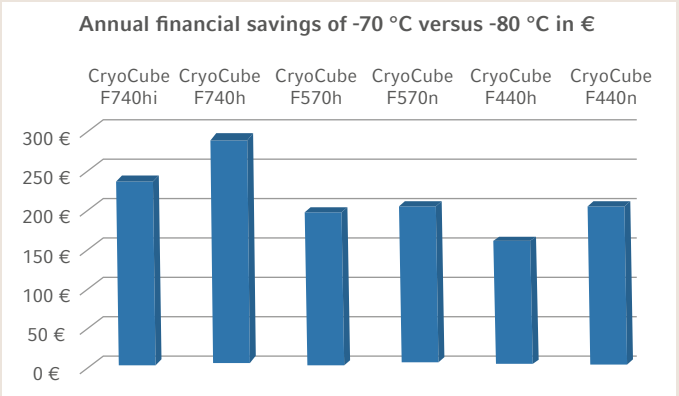

Figure 6: Average annual savings in Euro/ year when changing the set-point of an Eppendorf ULT freezer from -80 °C to -70 °C. The data are based on Eppendorf-external tests with 3 empty units (230 V) of each type in parallel and 20 °C room temperature. The average cost per kWh is defined as 0.21 € (EuroStat 2019).

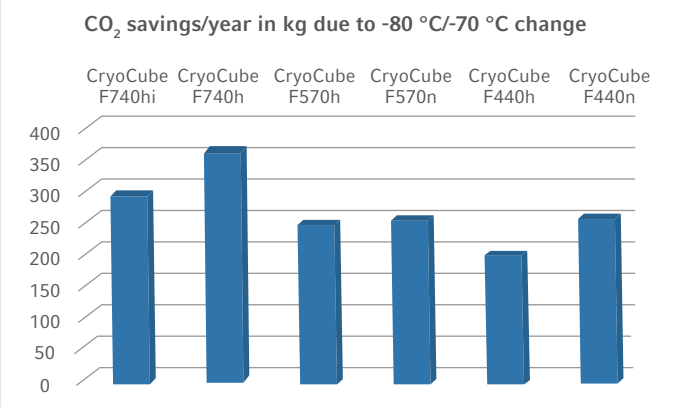

Figure 7: Average annual savings in CO_2/ year when changing the set-point of an Eppendorf ULT freezer from -80 °C to -70 °C. The data are based on Eppendorf-external tests with 3 empty units (230 V) of each type in parallel and 20 °C room temperature. The greenhouse gas emission calculation is based on www.eea.europa.eu 275 g CO_2/ kWh (2019).

Green energy

The Eppendorf production facilities have been gradually switched over to power originating from renewable sources. We can proudly announce that since 2021, nearly all products carrying the renowned Eppendorf logo have been assembled using 100 % renewable energy.
However, product assembly is only one aspect of energy-conscious action; the operation of laboratory equipment also requires electricity. If possible in your area, consider using green energy sources in your laboratory. Green energy is not that costly anymore. In many countries where green energy is available as an alternative, the price difference is very small or even zero.

Training

At first glance, the ULT freezer may seem like a simple device, but care should still be taken to ensure its proper usage. Quite often, the unit is shared by different people or even different labs.
We strongly recommend all users be trained on basic topics like how to properly open and close the door, how to store samples systematically, and how to perform regular maintenance tasks.

Maintenance and Service

ULT freezers run 24/7 for many years. A few regular maintenance tasks will extend the lifetime of the freezer and ensure optimal energy consumption. Remove dust from the heat exchanger and clean the air filter on a regular basis. Manual cleaning of snow/ frost/ ice on a weekly basis helps to ensure optimal performance. Ice-free door sealings (especially outer door gaskets) keep cold air inside the freezer where it belongs. Iced gaskets result in a constant loss of cold which needs to be replaced by a higher run rate of the cooling system (= higher energy consumption). Additionally, ice build-up can reduce the usable space within the freezer chamber, resulting in a higher power consumption per usable volume.

> An annual manual defrosting is recommended in which basic cleaning of the freezer can be combined with sorting and removing outdated samples. An organized freezer enables a more efficient usage of freezer space and provides storage for an increased number of sample vessels.

> Designate someone in the lab to be responsible for ensuring regular maintenance tasks are performed. Make a note on the freezer door when the last defrosting was done and when the next one is planned. For automated maintenance reminders, consider a digital system like VisioNize® Lab Suite.

Download your maintenance poster

Back up freezer
What should you do if your freezer fails? Although these situations are very rare, if it happens, it stays in your memory. These stories often start with an alarm notification in the middle of the night by security or by your remote digital monitoring systems. If the freezer has failed, there may be 20 or 25 racks full of samples that need to be transferred to another freezer. There are two options: You can split the racks into different freezers wherever you can find space or find an empty freezer. Large institutions may have one or two empty backup freezers that they keep running. In an emergency, backup freezers serve as a safe harbor for those samples which must be evacuated from a poorly or non-functioning freezer. A completely empty freezer enables a quick transfer and cooling of the samples back to -80 °C. But these backup freezers consume high amounts of energy which is often unecessary. In most emergency situations, the warm-up time of a broken unit takes many hours. If you receive notification at the time of failure, this leaves time to find and prepare an alternative. If the pull-down time of the backup unit is within 4-5 hours, this may be sufficient to protect your samples.
If you choose to keep a backup ULT freezer on hand, select a freezer with fast pull-down to avoid running it empty 24/7. But test the backup freezer regularly over the year like you do with fire extinguishers or similar equipment.

Longevity
When handled with care and maintenance, ULT freezers can be used for at least 10-12 years. There is no strict guideline when an old freezer should be replaced. New models often have lower energy consumption, but the production and delivery of a new unit requires a lot of resources. A freezer which consumes between 20 and 25 kWh/ day is worth a replacement as current models consume about seven to ten kWh/ day depending on their volume class. A replacement based on potential savings of, e.g., two kWh/ day, for example, should be discussed with the sustainability department.

Continuous learning
As scientists, we want to improve and to learn. For sustainability and sample management, the International Freezer Challenge is a good opportunity to improve lab practices and reduce energy consumption.
For this global competition, the non-profit My Green Lab and the International Institute for Sustainable Laboratories (I^2SL) partner to reward the best concept to improve cold storage and sustainability.
Encourage yourself to participate – it's easy: ULT freezer users are invited to compete with colleagues from around the globe. Labs and researchers can earn points by taking actions from Good Management Practices, Temperature Tuning, and other areas, as well as for sharing information about best practices. Awards are given to those who have done the most to save energy and improve their sample storage. Your participation benefits your science and the planet. Since 2017, the Challenge has saved over 14.5 million kWh In 2021, more than 100 organizations participated.
For Eppendorf, sustainability is paramount. Consequently, we are again a proud sponsor of the 2022 International Freezer Challenge.

Sample management
Many freezers may seem to be at capacity, but they are not filled in an efficient way. Why is this? On the one side, there are still many people using free-style bag systems or non-standardized tube racks of different sizes and formats instead of standardized freezer boxes in metal racks. The benefits of sorting systems are obvious: Short openings due to easier sample access keep the temperature at a constant level and require less energy for temperature recovery, while the volume of the freezer chamber can be used more efficiently. In a case of freezer failure, the transfer to another freezer is easy and fast.

In combination with standardized racks and boxes, effective management of samples is critical for maximizing cold storage space. Efficient processes for tracking and locating samples is best accomplished with a dedicated sample management software.
In addition to optimizing storage space, the software provides information about the exact storage location of a sample within the freezer prior to opening the freezer door. This allows for quicker sample location and reduced access time, resulting in less loss of cold air and therefore less energy usage for temperature recovery.

Access your eLabNext
30-day free trial

www.elabnext.com/eppendorf

Disposal of instrument

Our freezers last for many years, but if they need to be replaced, we kindly ask you to fulfill local requirements for disposal of these instruments. From the environmental perspective, there are two critical components where disposal requires special steps: The backup battery for the alarm system and the Li-battery of the control boards for the touch interface as well as the cooling liquids. The disposal of the latter depends on the type of refrigerants within the freezer.

We strongly recommend a certified local recycling partner with experience in instruments with active cooling. Keeping it "local" reduces the impact of transportation, and the "certified" aspect is recommended to ensure the safe and sustainable removal and recycling of the cooling liquids. Keep in mind, the classic cooling liquids of R404a and R508b must be completely removed and completely collected due to their high global warming potential (GWP). The hydrocarbon-based R170 and R290 are known to have little to no GWP, but there is risk in their chemical structure as propane and ethane are flammable and may be explosive. Their impact on the environment is -to current knowledge- limited.

For all these substances, the dedicated Material Safety Data Sheets (MSDS) are available on the Eppendorf freezer product webpages.

Decontamination

This piece of equipment was used in a laboratory and/ or was used to handle biological samples. Please keep in mind it is necessary to adequately decontaminate the freezer prior to disposal. Check local requirements. For more information, get in contact with your local biosafety officer and/ or waste officer. Check if your local recycling partner has special instructions and/ or documentation requirements. You may also use the Eppendorf decontamination form sheet as guidance.

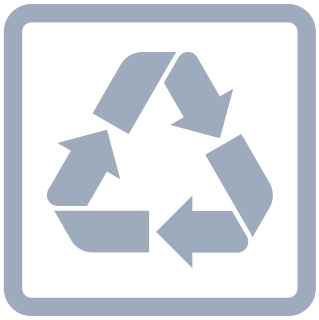

Figure 8: Disposal of lab equipment requires careful planning

Summary

Determining the sustainability of a ULT freezer and its related environmental footprint includes examination of aspects beyond just energy consumption and the type of cooling liquids used. Design and production in the factory, the shipment, independent certification and valid performance data, longevity, maintenance, and finally clear guidance on what to do with the instrument at end of life are relevant as well.

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