Radiology and Eco-Responsibility

On the road to "Green Radiology"

SOCIÉTÉ FRANÇAISE
DE RADIOLOGIE
& D'IMAGERIE MÉDICALE

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With the participation of

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Francelyne Marano, High Council for Public Health, President of the Specialised Commission on Environmental Risks

Laurie Marrauld, Ecole des Hautes Etudes en Santé Publique, lecturer specialising in the use of digital technologies in health

The team of the French Society of Radiology and its director, Julien Marcelle

CNEH, National Centre for Hospital Expertise

Snitem, National Union of the Medical Technology Industry

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Summary

Introduction

Why is the French Society of Radiology investing in eco-responsibility?

Radiological activity is now essential to the care of patients. Both screening and diagnostic imaging examinations and interventional radiology procedures have led to spectacular advances in improving the health status of patients and populations. However, any high-tech healthcare activity has an impact on the environment. It consumes goods (helium and gadolinium, for example), produces a large amount of waste - particularly in interventional radiology - mobilizes transport, builds premises with technical specifications related to the necessary radiation protection and compliance with hygiene standards, heats - and above all cools - its installations to guarantee the operation of the machines. Finally, it transfers and preserves images in quantity, permanently and archives them for a long time... In this respect, radiological activity must assess its impact on the environment in the broad sense. The benefit-risk balance is perfectly applicable since there is a real risk of contributing to the deterioration of the health of the population that radiological activity, like any diagnostic, screening and care activity, has the mission to preserve. In other words, while it is essential to implement eco-responsible behaviour, it is still essential to be able to simultaneously guarantee the production of quality and safe care for patients.

Beyond the "current" phenomenon that is the climate issue, the unavoidable societal fact that ecology represents or the State's stated commitment

to eco-responsible public services, radiologists, as actors in prevention and health promotion, have a duty to set an example in terms of eco-responsibility towards users and society as a whole. More broadly, radiologists have a duty to think and act for future generations, starting with juniors, students and interns in the specialty whose sensitivity to environmental issues is heightened.

While it is therefore essential to implement eco-responsible behaviour, it is nevertheless essential to be able to simultaneously guarantee the production of care as satisfying as the one we know today without sacrificing anything to the quality and safety of care due to our patients.

It is in this spirit that the SFR undertook in 2020 to initiate an “eco-responsible” approach to which the CERF “Ethics” group, placed under the responsibility of Professor Catherine Adamsbaum, contributed during the spring JFR in June 2021. Its guidelines are reproduced in the following pages of this White Paper.

Four working groups were then set up at the end of 2020 within the SFR and on the basis of a call for applications open to all, to carry out an inventory in four areas:

- Digital sobriety, a group coordinated by Prof. Pierre-Jean Valette.
- New technologies, a group coordinated by Prof. Loïc Boussel (heavy equipment) and Prof. Vania Tacher (robotics, connected devices).
- Contrast agents, a group coordinated by Prof. Alain Luciani.
- Waste management, a group coordinated by Dr. Audrey Fohlen.

The work of each group is summarized in the chapters of this White Paper and was also the subject of dedicated sessions/debates during the JFR21, the retransmissions of which are accessible on the SFR website.
The animation of these working groups called upon numerous organizations and partners that I would like to thank here for their contribution to our discussions: the Ministry of Ecological Transition and Ademe, INSERM and CNRS, the High Council of Public Health, notably through the participation of Ms. Francelyne Marano on the issue of nanotechnologies, AFPPE (French association of paramedical personnel in electroradiology), UniHA, SNITEM, Europharmat, The Shift Project, ARCEP, as well as François Gracia, engineer at the Montpellier University Hospital and lecturer at the IAE Paris 1 Panthéon Sorbonne.

At the same time, the SFR is involved in other initiatives dedicated to the eco-responsibility of health. Dr. Betty Jean represents our learned society in institutional approaches to assessing the carbon footprint linked to care, including that set up by the APHP “sustainable development” unit to identify the share of radiology. And since April 2021, under the leadership of President Jean-François Meder, the SFR has been a member of the Ceres collective (Collectif Écoresponsabilité en Santé) – see appendix p. 57. In addition, the SFR has launched a committee dedicated to eco-responsibility which will propose a roadmap for the months and years to come and will draw up regular reports on its implementation.

So many actions thanks to which the SFR is preparing to take up the challenge of technological, organizational and… sustainable innovation!

Pre Hélène Kovacsik
President of the SFR-FRI
President of the JFR 2021
Coordinator SFR Eco-responsibility group

Envaironmental impact of radiology: a medical literature still saparse

The medical literature is still poor on the effects of our practices on the environment. This is evidenced by the results of a search carried out on August 1, 2021 on the PubMed website**, from the keywords below, publications on the theme of the environmental impacts of medical imaging.**

"Carbon footprint radiology" : 10 Publications

- 4 concerns air travel for congress travel
- 1 concerns the need to turn off workstations (consoles) after use at night (1)
- 1 compares the power consumption of 3 interpretation consoles (2)
- 2 concern medical activity in general
- 2 use radiology to evaluate bamboo or natural objects (out of scope)

That is to say only 2 studies concerning our professional practices (excluding congresses)!

« Greenhouse gas radiology » : 9 publications

- 1 concerns the emission of greenhouse gases by an academic interventional radiology center (3)
- 1 compares the CO2 emission of 3 imaging techniques (US, CT and MRI) in abdominal imaging (4)
- 1 concerns the use of waste recycling (5)
- 1 assesses the impact on CO2 emissions of telemedicine versus patient transport
- 5 are out of scope or already present in the previous group

« MRI carbon footprint » : 1 publication

- 1 "letter" on the "unsustainability" of our imaging practices in view of their environmental cost (6)

« CT carbon footprint » : 1 publication

- 1 publication measures the carbon footprint of the scanner in 2014 (7)

« Climate change radiology » : 1 publication

- 1 publication of a call for awareness (8)

« Environmental radiology » : 1 publication

- 1 publication on carbon footprint based on imaging modalities (9)

« Conservation of Energy Resources / economics* Radiology » : 1 publication

- 1 publication on the electrical consumption of our devices (10)

« Gadolinium footprint » : 2 publications

- 1 article (119) and 1 editorial (120)

Publications still limited

Thus, a small number of studies, most of them very recent, deal with medical imaging (see references in the box). All are single-center with a carbon footprint assessment methodology reflecting limited resources compared to those devoted to it by the industry. All also show that substantial savings are possible by changing our console management and waste recycling practices or by favoring imaging techniques according to their environmental impact (by preferring ultrasound to CT scans and especially MRI). Finally, it appears that the necessary air conditioning of our rooms is by far the main source of CO2 emissions.

A necessary investment

However, there is a real awareness in medicine today and the objective of decarbonizing health is becoming a growing concern (8). The evaluation of our practices and the effects of "eco-responsible" behavior is essential even if there are multiple obstacles. First of all, it is difficult to individualize the effect of radiological activity from the more general effect of the functioning of a healthcare system sharing many tools and activities (computers, secretarial work, access to patient records, archiving, transport, etc.). The methodologies for evaluating our activities are also foreign to us and are costly. Furthermore, no earmarked funding exists for this type of study: what patient benefit or what economic return can be justified?

The fact remains that the practice of radiology is possibly a significant source of the carbon footprint of the patient journey in relation, on the one hand, to the manufacture and transport of machines and tools and, on the other hand, to their use: air conditioning, exponential production of data to be transferred and archived, patient transfers, use of single-use equipment with multiple packaging or recourse to technologies using rare resources (helium, gadolinium, etc.). And yet, archiving reduces redundancies in examinations. Interventional radiology procedures sometimes replace more onerous care that also consumes resources. Screening reduces mortality. How then can we really assess the impacts of our activities? So many questions that make it all the more essential for our discipline and its practitioners to invest in the field of eco-responsibility.

Prof. Hélène Kovacsik

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Eco-responsibility & ethics

As the 2021 *Journées Francophones de Radiologie* have shown, radiology must conduct the necessary reflections for an eco-responsible approach. However, the means to achieve this may raise certain ethical questions, particularly in terms of the balance between eco-responsibility and quality of care, i.e. in terms of benefit/risk. The reader will find some avenues for reflection below.

What are the impacts of reducing digital pollution?

Digital sobriety is a necessity to improve the eco-responsibility of medical imaging by reducing its carbon footprint (see p. 21). However, at the same time, the growth in the volume of raw data and reconstructed images is constant due to rapid technological developments. The multiplication of data helps to increase diagnostic confidence. The retention of this data, even heavy data, can be of diagnostic and forensic interest. The implementation of guidelines and protocols to limit the volume of digital data is essential but raises many questions, both individual and societal: Should we determine key images to transfer/archive? Is there a loss of opportunity for the patient if it is no longer possible to fully access old imaging tests? Can the digital patient record be a solution to avoid copying the same data to multiple locations (PACS, CD, Cloud, etc.)? Does the creation of imaging examination protocols and "digital eco-conducts" by the SFR not go against the individual freedom of the radiologist in the exercise of his profession? How will these protocols evolve? Will they be able to keep up with the curve of medical and technological progress? Can the choice of data loss constitute a brake on the expected performance of artificial intelligence algorithms?

More eco-responsible purchases, but at what price ?

The trade-off between environmental cost and economic cost is a recurring problem of eco-responsibility in all sectors of activity as in daily life. Driving an electric vehicle (if its life cycle is more environmentally friendly) or eating organic, for example, is not within everyone's budget. In radiology, this balance is also difficult to find. For example, buying cheaper disposable sets in bulk (and throwing away unnecessary new components) is preferable in terms of cost. Conversely, buying only what is needed for the sample to avoid waste and limit waste is more expensive and can ultimately limit access to care. What is the right balance between these two positions? Beyond this example, the question arises of systematically introducing eco-responsibility criteria into specifications and purchasing processes (composition of kits, packaging, etc.), as many companies are beginning to do. An approach in which radiologists must take part in order to arbitrate, in light of their needs as practitioners and the quality of care, the choices between economic and environmental imperatives in collaboration with buyers and pharmacies.

Favouring short circuits and products made in France represents another lever for eco-responsibility.

This avoids the CO_2 emissions generated by shipping or flying from countries on the other side of the world. Local employment is also promoted while avoiding condoning unregulated working conditions that do not always respect fundamental human rights. However, structural trade protectionism undermines the principle of free trade, which some consider to be economically ethical. Where should we place the cursor?

Teleradiology: less CO_2 at the risk of degrading the quality of care?

The impact of telemedicine activities on the environmental footprint remains a vast field that has not yet been assessed. As far as teleradiology is concerned (which concerns exclusively diagnostic radiology), the situation is complex. It does not make it possible to avoid the need to travel the patient to a radiology centre with the appropriate equipment to carry out the examination. Moreover, while teleradiology can sometimes reduce territorial inequalities, it does not solve the issue of the insufficient demography of radiologists. In addition, teleradiology deprives the patient of his or her "radiological consultation" for the rendering and explanation of the result and its consequences. The framework for the operation of teleradiology must therefore be well defined by radiologists within the framework of territorial organizations, taking into account all local resources to avoid a degraded form of care with a decrease in its quality. On the theme of access to care, the following question also arises: is it ethical to substitute a minimally invasive but non-accessible first-line technique by another more "invasive" technique but available locally. Et dans ce cas-là, ne vaut-il pas mieux déplacer le patient malgré le coût écologique du transport ?

Products that perform well for care but are dangerous for health?

Medical imaging uses products and materials that are likely to pollute flora and fauna, to have a biological risk that could harm human health, and even to modify DNA and the genome. This issue is well known for exposure to X-rays and is the subject of a European Directive. This is also the case for injected products for diagnostic purposes such as gadolinium chelates, products for therapeutic purposes such as embolization microparticles ranging in size from 50 to 900 microns, materials such as "drug eluting", angioplasty stents and balloons, titanium or nickel implants or immunotherapy by in situ injection and anti-tumor vaccines. If these are products that contribute very significantly to the improvement of patient care, their use must be accompanied by active monitoring aimed at improving knowledge of their potential impacts on living organisms and the environment. More generally, this is an ethical reflection to be carried out on the era of the "augmented" man, its benefits and risks.

Chapter written on the basis of the work of the SFR Ethics Group under the responsibility of Prof. Catherine Adamsbaum, Bicêtre Hospital (AP-HP), Paris-Saclay Faculty of Medicine

Digital education: a necessity to make medical imaging eco-responsible

Like the entire healthcare sector, medical imaging is increasingly technological. For the benefit of patients but much less for the planet and the climate when we know the many impacts of digital technology on the environment. Manufacture and use of equipment, storage and exchange of data, software, printing, etc. radiology consumes energy, emits CO2 and draws on the reserves of many natural resources. While it is far from being the only one to do so, it has the means at its disposal to take the path of digital "sobriety", without limiting the use of digital technology, which is increasingly contributing to strengthening the quality of care.

What's the problem?

While digital technology can replace paper, plastic films and chemicals used for films and CD-ROM burning, limit travel or improve information sharing, and appears to be a promise of preserving the planet's resources, there is nothing immaterial about it from an environmental point of view. Its implementation is based on equipment (smartphones, computers, datacenters, servers, fiber optics, etc.) whose life cycle, from their manufacture and transport to their use, is a major consumer of natural resources and a generator of pollution. Their manufacture therefore requires metals (some of which are rare and in the process of being depleted) from all over the world, the extraction of which is most often very expensive for the environment (water, fossil fuels, etc.). Their use is then energy-intensive, and therefore generates significant CO2 emissions responsible for climate change. Et en fin de vie, digital technology produces waste that is complex and underdeveloped to recycle.

All experts agree that due to the acceleration of the digitalization of society and the economy, the environmental impact of digital technology will also spiral out of control. Its direct energy footprint is already increasing by 9% per year, or a doubling every 8 to 10 years. And data exchanges continue to grow at a rate of 25% per year. The trend is the same for connected objects, which are expected to reach 48 billion in 2025, which will account for between 18% and 23% of the impacts of digital technology. Another example : according to the High Council for the Climate (HIC), the deployment of 5G, due to the deployment of new terminals (smartphones, virtual headsets, etc.) would lead to an increase of 18 to 45% in the carbon footprint of the digital sector in France by 2030.

Like all sectors of activity, health, whose digitization is accelerating year after year, contributes to this digital pollution. And his contribution is far from trivial. It is estimated that it is responsible for 5.1 % of national CO2 emissions in France (The Shift Project). Hence the need for the entire health ecosystem to act in favor of greater "digital sobriety". However, this should not mean renouncing the benefits of digital technology in patient care – and there are many of them in medical imaging – but rather limiting its environmental impacts. This applies at all stages of the life cycle of the multiple pieces of equipment used in healthcare establishments and radiology departments (computers, printers, X-ray and ultrasound machines, scanners, MRIs, etc.) : design, manufacture, and use and end of life.

Digital pollution in numbers

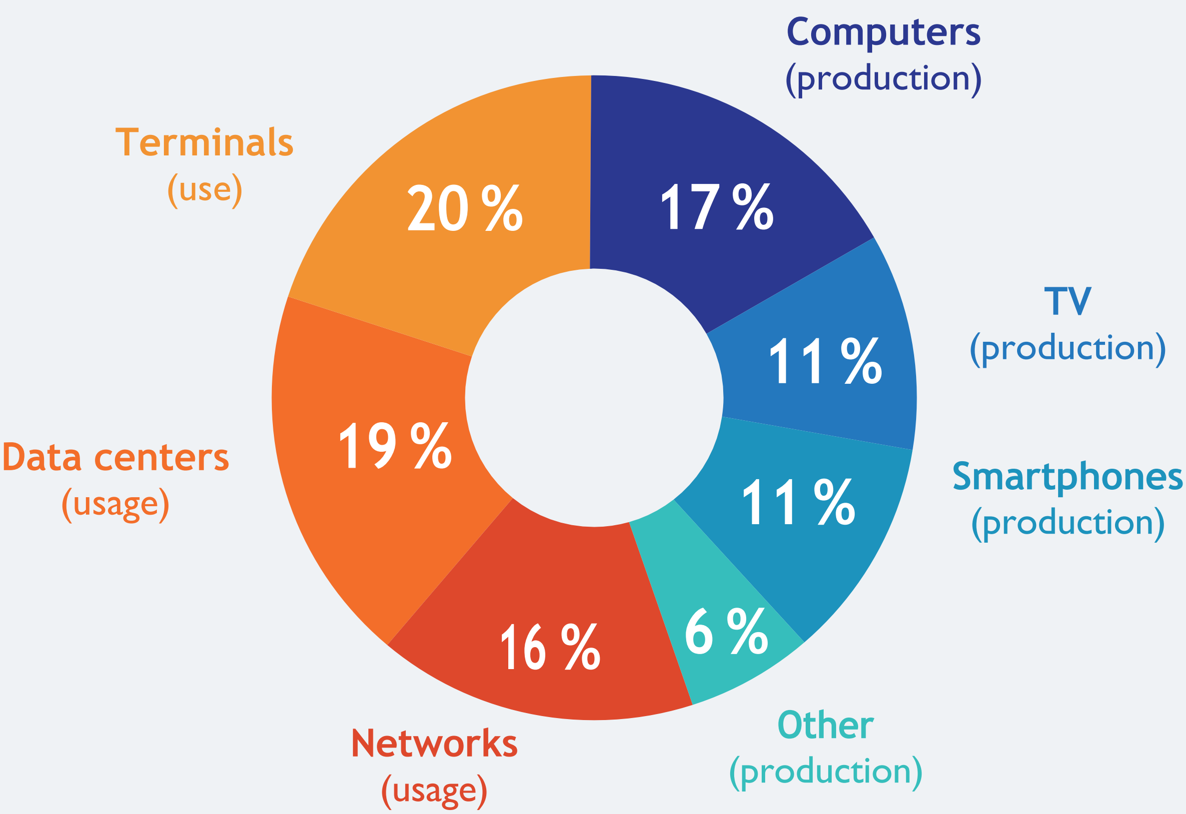
- **4 %** : this is the share of digital technology in global greenhouse gas emissions , twice that of air transport
- If digital technology were a country, it would have **2 to 3 times** the footprint of France.
- **5.1%** : this is the share of national CO2 emissions generated by the health sector France (The Shift Project)
- **More than 5%:** this is the share of internal IT in the carbon footprint of an average university hospital (ministerial report on the environmental impact of digital health).

190,000 tonnes of CO2 equivalent per year: this is the carbon footprint of the 470,000 IT workstations in public health establishments in France, the equivalent of more than 1 million round trips from Paris to Marseille by plane for one person.

- **1 MRI would** consume as much energy as **700** average European homes

(«Evaluation of miscellaneous and electronic device energy use in hospitals.» World Review of Science, Technology and Sustainable Development).

- **Global energy consumption of digital technology :**



Source : The Shift Project 2018, à partir de Andrae & Edler 2015.

Levers for action

Modern radiology is by definition an activity that creates and consumes digital data. In fact, digital eco-responsibility in radiology must focus on the environmental consequences of the use of medical images (acquisition, post-processing, archiving, network transmission, etc.) related to the use of computer systems that consume energy (carbon footprint) and bandwidth on the networks. However, since it is a question of "pollution", the reflection should also extend to the problem of the accumulation of medical data (images or others) that are sometimes useless (hypertrophy of databases, dilution of relevant information, etc.), a source of waste of time for doctors, or even loss of opportunity for the patient. In addition, an approach to digital eco-responsibility should also take into account the environment on which the performance of radiological examinations should be able to be based (patient medical file, networking of all medical actors, indexing of data, etc.).

Thus, even if it must address all subjects, the proposal is to focus at this stage on the reflection on what is really feasible, with concrete results, and without disproportionate constraints.

Some have identified ways to limit the archiving of radiological images over time, duplicate examinations (CDs imported on PACS), or even systematic reconstruction. For the time being, these proposals are hampered by the problems of legal constraints, the absence of a shared common medical record, and the lack of mastery of post-processing tools images from clinicians. They will not find an immediate solution without significantly limiting access to the data necessary for optimal medical practice. Hence the choice to focus on four areas of work for which real action plans are possible, even if they still raise many questions to implement them : three in the context of a reflection on the "pollution" linked to the unreasoned accumulation of medical data and a fourth on the possibilities of analysing the carbon footprint of the activities of imaging services.

Controlling the demand for imaging

This is a vast problem that has been the subject of numerous action plans and other recommendations for the requesting doctors in France. It is clear that the results are mixed in a change in medical practices that sees technique take precedence over the clinic, and which often proceeds (especially in the context of emergencies) to a delegation of examination indications to juniors who may lack the experience of many years of practice. Would it be acceptable to put statistical data on the relevance of imaging indications online within institutions, or even to apply financial penalties to the least virtuous teams (or applicants)?

Optimize the choice and titles of series

The examinations circulate on the occasion of the sharing of data between participating institutions (multi-site RCPs, collaborations for the care of patients), thus showing that practices (MRI, in particular) concerning the transmission of series are really useful and the choice of titles on our examinations of comprehensible series are not always a primary concern. Could recommendations from university or professional institutions of radiology change practices : homogenization of the names of the series for better identification and selection, implementation of more relevant examination protocols according to the ALARA principle (as low as reasonably achievable) combining justification of choice, optimization and limitation to what is useful?

Improving the conditions of access to relevant medical data

The accumulation of information can hardly be controlled, and the indexing of data still has serious technical and organizational limitations.

Artificial intelligence could provide solutions to recurring difficulties in accessing relevant data. Setting up PACS systems allowing access to the territorial patient file, and not limited to the establishment, makes it possible to avoid the unnecessary repetition of imaging examinations. Artificial intelligence applied to the patient record data system also makes it possible to select relevant clinical and paraclinical data indexed in the patient's digital record for optimal specialized care without the need to systematically open all sub-records, and thus shorten the duration of use of our PACS servers and consoles.

Estimating the carbon footprint of imaging services

This is a technically difficult process, but one that is being undertaken by many sectors of activity. Several hospital institutions (APHP, Lyon University Hospital) have already included this issue in their organizational projects

Digital Sobriety: The Digital Health Agency's Recommendations

- **Before using a digital service or equipment**

Prioritize the services to be deployed, according to the expected benefit and the issues targeted.

Promote eco-design approaches When purchasing new equipment and services, promote responsible IT purchases, check the need and choose suitable equipment or services (not oversized).

- **During the life of the equipment**

Maintain existing equipment to ensure its sustainability

Optimize the use of printing and print only what is really needed.

Lighten emails by reducing attachments (promote file sharing and dematerialization) The number of recipients to those actually affected Switch off completely and do not leave computers on standby when not in use. Uninstall unused software, clean servers and computers regularly to avoid the accumulation of digital waste that consumes energy unnecessarily.

- **At the end of life**

Favouring the reuse of equipment in the context of solidarity operations

Use the collection of WEEE (waste electrical and electronic equipment) via a professional service provider to promote recycling and the clean treatment of non-recyclable waste.

under the guise of preliminary research. The SFR participates in the action set up by the "Sustainable Development" department of the APHP to quantify the carbon footprint in several patient pathways. Three typical pathways have been identified : a patient followed for chronic diabetes, a day hospital pathway for an operation and a typical pathway for chronic cancer treatment with chemotherapy. The objective is to quantify all the steps of the management of these 3 typical patients to model the carbon footprint longitudinally. Within these courses, the proportion related to imaging will be quantified in order to better understand the share of the carbon footprint between the share of image production, that related to equipment and those related to the visualization and archiving of digital data.

Chapter written with the contribution of Dr. Betty Jean, Lariboisière Hospital (AP-HP) and Prof. Pierre-Jean Valette, Lyon University Hospital

To go further

Pour un numérique soutenable, ARCEP report

L'impact du numérique en santé, Interministerial Delegate for Digital Health, Ethics Unit GT6) – Digital Responsibility

Déployer la sobriété numérique, The Shift Project 2020

Décarbonons la santé pour soigner durablement, The Shift Project 2021, p 121-126

The "learning" radiologist

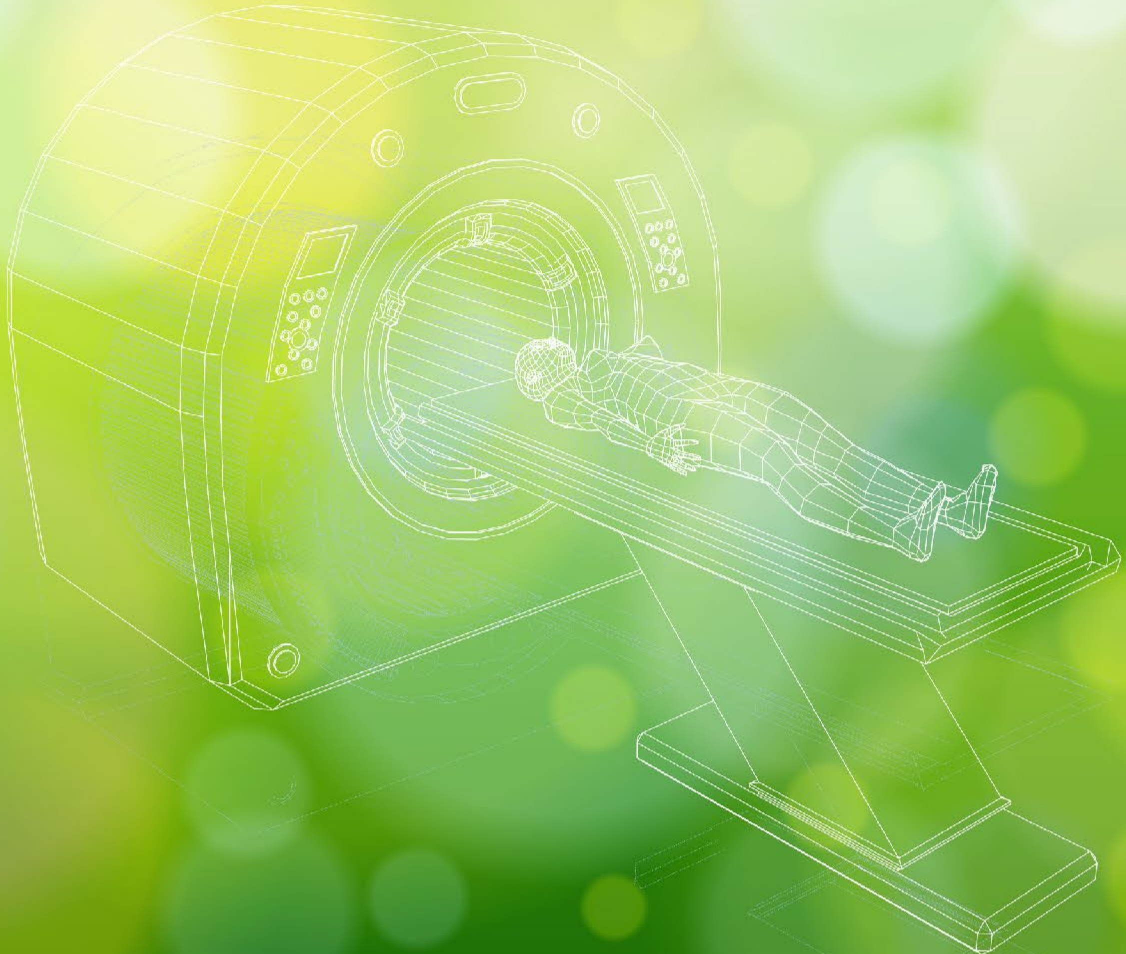
The SFR has proposed recommendations for a more eco-responsible practice to the radiologists attending the conference in the use of their tools (computers, smart phones) which also apply to the daily professional management of radiology.
(see appendix p. 59)

A shared digital eco-responsibility...

In a CNEH survey in which 163 hospital and library radiologists participated, they answered the following question: "*Faced with the increase in data production, access and storage, with which actors should we work as a priority to identify and promote good practices on the proper use of data in radiology and imaging?* ». Their responses testify to the need to mobilize all stakeholders in the discipline's ecosystem :

- **To information system managers, management or companies: 86 %**
- **To the management of the establishment: 74.5 %**
- **From users: 75.2%**
- **Among prescribers: 80.9%**
- **With teams: 84.1%**
- **Other: 22.3%**

How can medical imaging equipment make radiology "greener"?



Are ever more powerful and efficient machines compatible with the eco-responsibility of our specialty? ? Yes, provided that all parties are mobilised including radiologists themselves, to reduce the environmental footprint to all stages of the equipment life cycle.

What's the problem?

The equipment needed for medical imaging has an environmental impact throughout its life cycle. During their manufacture, they consume raw materials and energy. Their transport from production and assembly sites to France is a source of greenhouse gas (GHG) emissions that is all the more important depending on the remoteness, the mode of transport used and the nature of the packaging. Their use is also energy-intensive (operation of machines, cooling, air conditioning, etc.), especially when they cannot be put on standby or turned off when they are not in use (between two patients or at night) or call on consumables and scarce resources (helium, gadolinium, etc.). Their use is also a source of digital pollution through the increasing volume of data and images produced and archived (see chapter on digital education). Finally, at the end of its life, the renewal of equipment required by its obsolescence or encouraged by the arrival of new, more efficient models and systems, generates waste, part of which is not recovered and recycled, when the machines are not refurbished or resold on the second-hand market.

Levers and avenues for action

Eco-design

Manufacturers have a major role to play in the design of machines to reduce their ecological footprint at all stages of the life cycle (production, use, recycling) thanks to numerous levers : choice of materials, location of production, choice of packaging (cardboard rather than wood, for example), artificial intelligence and other innovations to improve the quality of data and images to optimize use and extend the life of machines, "stop&go" systems for automatic standby, anticipation of recycling, reduction of the weight and size of machines to reduce cooling needs, etc. This eco-design approach is increasingly being carried out by the sector (see appendix p. 52 for the contribution of the SNITEM).

The MRI of tomorrow

Helium, an exhaustible and sensitive fossil resource for MRI technology, will be exhausted by 2035 and, as of now, technological advances are being made in this direction : MRI using less helium or even without helium are in the plans of industrialists.

Labelling system

As is the case in household appliances, smartphones, cars or food (Nutriscore), a simple and understandable labelling system for all noting the carbon footprint or energy consumption of machines (overall or per patient/examination) would allow commuters and buyers to favour equipment that is more environmentally virtuous.

The environmental impact of radiology equipment in numbers

- Medical imaging accounts for **4 %** of a hospital's energy consumption and the equivalent of the consumption of **852 people** for a year.
- An ultrasound consumes **650 g of CO2** per examination, compared **to 2.1 kg for a CT scan** and 13.72 kg for an MRI
- **32 workstations consume** 53,0000 kWh **per year**, the equivalent of a hundred barrels of oil
- In Europe, the energy loss due to the absence of the "sleep" or "off" mode of X-ray machines has been estimated at **49 TWh in 2020**.
- Up to **45%**: this is the potential energy saving that can be achieved if the consoles are turned off after one hour of inactivity
- The transport of a machine by land or sea freight is **55 times less** polluting than by air freight.
- A scanner produced **160 megabytes** in 2020 compared to **66** in 2011.

The latest MRI models require **20 liters** of helium compared **to 2,000 liters** for previous generations.

- **User Education**

Manufacturers could provide a guide to users to optimize the energy consumption and use of equipment to reduce its carbon footprint and extend its lifespan.

- **Purchasing**

Although there are currently environmental criteria in calls for tenders for the acquisition of new machines, their weight remains limited today. Radiology and other specialties that use heavy equipment must work with central purchasing bodies, buyers and facility management to strengthen the weight of these criteria in the purchasing process and allow for more transparency.

- **New business models**

As is the case in other consumer sectors (mobility, music, auto-mobile...), the transition from a model based on the sale of products to a model based on service (economy of functionality or use), promotes the durability and longevity of equipment : manufacturers are encouraged to extend the life of machines with successive users in order to increase their profitability.

- **Upgrade**

As industry is beginning to propose, upgrading a machine's systems and components can improve its performance and extend its lifespan, thus reaching 7 to 10 years of operation without loss of quality for patients.

- **Second life**

At the end of their use, medical imaging machines can follow two pathways : reconditioning provided by the manufacturer which allows, after the renewal of the components that need to be replaced, upgraded, and remarketed with the same performance as new equipment; Resale on the second-hand market. In France, for regulatory reasons, refurbishment remains anecdotal compared to the practice of many countries. Joint work by radiologists and industry with the regulatory authorities would make it possible to develop this virtuous circular economy approach.

Chapter written with the contribution of Prof. Vania Tacher (CHU Henri Mondor) and Loïc Boussel (CHU Lyon) and Jérôme Chevillotte (SNITEM)

"Eco-information" still insufficient

When radiologists are asked whether manufacturers have highlighted the eco-responsible nature (design, transport, consumption, obsolescence, recycling, etc.) equipment during the latest acquisitions of high-tech imaging equipment, the answer is clear :

- "Not at all" 53,7 %
- "very partially" 30,9 %
- "Yes, but like the others": 10,7 %
- "Yes in a significant way" : 4,7 %

(CNFH survey 2021)

Reducing the environmental impacts of contrast agents

While the control of the health risks of contrast agents is highly regulated, this is not yet the case for the environmental risks of gadolinated products. But the first initiatives are being put in place to reduce the often little-known impacts of their daily consumption in medical imaging departments.

What's the problem?

Gadolinium, which has been used since the late 1980s as a basis for contrast agents in MRI scans, is one of the so-called "rare earth" metals (see box) that are present in the Earth's crust and, at very low concentrations, in ocean water. All of the Gadolinium atoms available on the planet date back to the birth of the solar system more than 4.5 billion years ago. It is therefore not a renewable resource. Its reserves are therefore limited while remaining relatively abundant. On the other hand, the extraction of Gadolinium from the rocks in which it is present is complex. The same goes for its refining, which uses chemicals. In addition to this complexity, there is a high environmental cost . Mining is accompanied by releases of radioactive elements (thorium, uranium, etc.) into the atmosphere and water. Its chemical treatment is also a major source of pollution. But Gadolinium's environmental footprint doesn't stop there. Its use in radiology results in discharges into water. Once injected, it is urinated and, in the current absence of treatment by wastewater treatment plants, ends up all over the world in rivers, groundwater, tap water, and finally in the ocean, where it is absorbed by algae and

Rare earths and Gadolinium in numbers

• The use of rare earths :
3 g of in a smartphone
0.3 to 4.5 kg in a car
from **200 kg to 1 tonne** in a wind turbine
0,79 g in a 10 mL syringe of a gadolinated contrast agent.
The Earth contains **1.15 billion tons of** Gadolinium

• The Gadolinium market is entirely dominated by China, which refines **90 %** of the world's volumes.

• Radiology accounts for **5 %** of global Gadolinium consumption.

• The consumption of Gadolinium by radiology has grown exponentially in recent years due to the multiplication of MRI examinations and now amounts to **3 million doses** per year in France.

• An MRI machine consumes an average of **3.2 kg** of Gadolinium per year.

• On average, **15 %** of the volumes of gadoline contrast agents contained in syringes are not used and end up in the trash, the equivalent of **2 tankers** per year.

85 % of the Gadolinium present in the contrast agents urinated by patients is released into the environment (rivers, groundwater, oceans, etc.).

the plants on which seafood feeds with potentially harmful in vitro effects on its development. The same applies to the remaining amount of product doses that are not used daily in the pre-dosed syringes. It should be noted that 100 % of the Gadolinium released into the water comes from human activities and in the first place from medical imaging services...

Levers and avenues for action

• Recycling of unused doses
Previously non-existent, the recovery of the unused quantity in doses of gadoline contrast agent is now possible thanks to the creation of MeGadoRe (Medical Gadolinium Recycling), a new collection solution developed at the Bretagne Occidentale University (Brest), by a multidisciplinary team including radiologists and supported by industrial and academic partners. Launched in the Grand Ouest in 2021, this initiative is currently being rolled out in France and neighbouring countries. The principle is to make 1.5-litre vials available in medical imaging centres, which, once filled (at an average rate of 2 ml per injection), are recovered and then transported to a factory located in Charente Maritime. There, the chelated Gadolinium is reprocessed and resold to manufacturers for non-pharmaceutical use.

For more information, contact MeGadoRe by e-mail at the following address: contact@megadore.org

• Conditioning
In several countries, Gadolinium is marketed in vials in which radiology departments take the amount needed for each injection. This is not the case in France where it is sold in pre-filled doses. This conditioning can be explained by the precautions taken by the ANSM since the contaminated blood affair. However, discussions are underway with the ANSM to consider packaging in vials in the future, if all health safety conditions are guaranteed.

• Patient urine retrieval
Reducing the environmental impacts of gadolinia contrast agents used in medical imaging cannot be achieved without finding solutions to treat patients' urine (which contains 85% of Gadolinium released into the environment). However, this recovery process, which must be done within 4 hours of the injection, is complex to implement. It is therefore still to be developed, which is what MeGaDore is working on.

Chapter written with the contribution of Prof. Alain Luciani, Henri Mondor Hospital (AP-HP), Prof. Jean-Alix Barrat, geochemist at the Bretagne Occidentale University and Prof. Duraïed Ben Salem, neuroradiologist, Brest University Hospital and Bretagne Occidentale University.

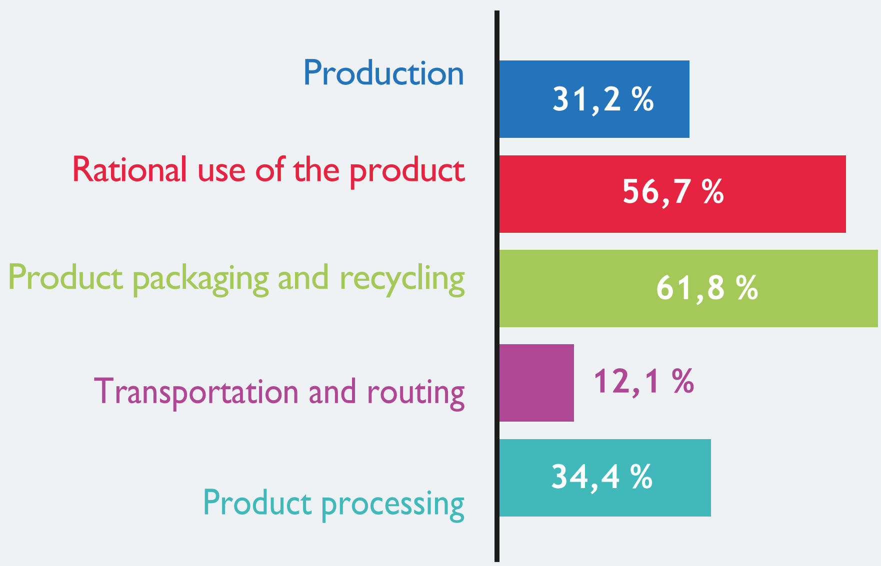
Manufacturers begin to deploy iodinated contrast agent recycling solutions

Experiments in collecting urine from hospital radiology or cardiology patients who have received an injection of iodinated contrast agents have begun in Germany. Initial results show that 75 % of the injected dose could be collected. The collected urine is then transferred by the collector to an incineration plant. It now remains to analyse the complete environmental assessment of this experimentation before deploying this recycling process more widely.

• GE (General Electric) has set up a circuit for the collection of doses of unused iodinated products in Northern Europe and, recently, in France . 500 imaging centers, including 60 in France, are concerned and have specific containers. The recovered products are reprocessed and resold to non-pharmaceutical industries.

Rational use and recycling acclaimed by radiologists

In a CNEH survey conducted in 2021 and in which 163 hospital and private radiologists participated, they answered the following question: « Regarding contrast agents used in imaging, what are, in your opinion, the 2 main subjects to be worked on in terms of eco-responsibility? ».



Conditional future of nanomaterial-based contrast agents

Nanomaterials, the definition of which is regulated by the European Union, must contain at least 50 % nanoparticles (particles with a dimension of 1 to 100 nanometers, one nanometer measuring one billionth of a meter). Some are found in nature (sands from the Sahara, ash from volcanoes, etc.), others are manufactured. Although nanomaterials in the form of powder were already used in the Middle Ages to make stained glass, their real development began at the end of the twentieth century thanks to physicist researchers working on the quantum scale. Since then, many industries have used them, such as agri-food, cosmetics and health (medicines) because of their innovative properties.
However, their use, which can be harmful to human health and the environment, is closely monitored. In recent years, for example, the French authorities have banned the use of titanium dioxide (E 171) in food products. More broadly, the use of nanomaterials is subject to authorisations from public agencies (ANSM, ANSES) as well as permanent monitoring by the High Council of Public Health.
In radiology, nanomaterials have appeared in contrast agents based on Gadolinium, Manganese, Magnetic Nanostructures, Iron Oxide or Dysprosium, for various applications including hepatic, lymph node or atheromatous plaque imaging. Magnetic nanostructures can also be proposed for targeted therapeutic actions (drug guidance, dynamic phototherapy, etc.) Not yet on the market, these products are still being experimented on and tested on animals to find out what happens to them in the body and over time. Other projects are being studied. More recently, for example, research has begun to test different metals at the nanoscale to develop contrast agents needed for new photonic counting scanner technologies. But whatever its purpose, this work will only lead to a successful outcome if it is demonstrated that there is no danger to humans and the environment.

You said rare earths ?

Rare earths refer to **17 metals** : scandium, yttrium, and the fifteen lanthanides (Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium), whose exploitation began in the forties and which are widely used in technological products (electric vehicle batteries , LEDs, smartphone chips, laptop screens, wind turbines, radars, etc.). Contrary to their name, these metals are not so rare. Some, such as cerium, are as widespread in the Earth's crust as other more common metals such as copper. The same goes for Gadolinium.

Sorting and waste management is also the business of radiologists

Day after day, medical imaging produces a lot of waste: films, CDs, paper, effluents, various care equipment, packaging... Some are dangerous, others are not. But all of them are a potential source of pollution or risks to human health. To limit these impacts, radiologists and healthcare institutions have many levers of action at their disposal.

What's the problem ?

In France, the health sector generates three times more waste each year than that produced by the population. Imaging departments or cabinets are major suppliers of waste : emitters of films (for departments not equipped with PACS), paper (folders, minutes, etc.), CDs, Waste Assimilated to Household Waste, computer equipment (computers, printers, etc.), light bulbs, batteries, etc. They also generate Healthcare Waste with Infectious Risks (see opposite), particularly in interventional radiology, the treatment of which causes an environmental impact 10 times more harmful than conventional waste. Like all health waste, medical imaging waste is a source of pollution. Landfilling or burying them emits methane that persists for hundreds of years, and their incineration – treatment of 80% of Healthcare Waste at Risk of Infection and Similar Healthcare (DASRI/DASRIA - see box) - generates emissions of CO_2, toxic gases (dioxins) and toxic ash. In addition to the environmental impact of health waste, the cost of collecting and treating it represents significant amounts of significant expenses for healthcare institutions. And the future will not change the situation, quite the contrary. In the coming years, the amount of the General Tax on Polluting Activities (TGAP) and the landfill tax, for example, will increase significantly.

Waste in figures

- **5 %** of annual CO_2 emissions : this is what waste recycling in France avoids, which is equivalent to the entire French air transport system or **20 %** of the emissions of the car fleet. (Source: ADEME-Federec)
- **483,000 tonnes** of CO_2 avoided, i.e. **4 349,000 trips from** Lille to Marseille by car : this is the 2020 carbon footprint of the recycling of electronic waste by Eco- system. The regeneration of materials and energy recovery have made it possible to avoid **904,000 tonnes** of CO_2, from which **421,000 tonnes** generated by the transport and treatment of waste must be deducted.
- **1 ton** of recycled paper saves **700 to 800 liters** of oil.
- **40 types** of waste are generated by a healthcare facility. **80% of** healthcare waste is comparable to household waste and is not hazardous, the **remaining 20%** is considered hazardous (infectious, toxic or radioactive).
- **3 to 6 kg** per bed per day. This is the amount of waste produced by a hospital, three times more than a resident. Hospitals generate **700,000 tonnes** of waste each year, or **3.5%** of national production.

Levers for action

• Reduction at source

The best waste is the one we don't produce! Hence the importance for medical imaging to optimize the way in which reports and images are disseminated, but also to manage requests for examination with their correspondents, according to the principle of just need. "0 film" and "paperless" are areas for improvement, while not forgetting that digital waste, which replaces physical waste, emits CO2.

• Selective sorting

Selective sorting, which consists of separating waste according to its recyclability (paper-cardboard or some plastics but not all) is the very foundation of any waste management policy. As bad sorting is useless sorting, its implementation requires real education in sorting instructions and gestures. Training and raising awareness of medical imaging professionals (radiologists, technicians, secretaries, caregivers) on these issues is therefore essential. Similarly, it is necessary to have suitable bins and collectors in sufficient numbers in radiology rooms and intervention theatres as well as in offices and break rooms.

• Eco-responsible purchasing

The challenge is to encourage suppliers to develop an eco-design of their products, in particular by setting up sustainable development criteria in the specifications of calls for tenders, to integrate the cost of energy, the cost of waste disposal and the carbon cost. F. Gallois, director of the consulting firm Management Radiologie, cites the example of lead aprons purchased by two different imaging departments from two different suppliers : the packaging of the decks delivered by the first represented ten times more waste than that of the second...

• Savings

In the current context, the budgetary argument can encourage the management and administration of a health institution to optimize its waste management. Because the bill paid each year by hospitals is far from negligible. A university hospital with 2,500 beds spends an average of more than €1 million per year on waste assimilated to household waste (€350 per tonne), €660,000 on waste (€600 per tonne) and €72,000 to €270,000 on toxic waste (WEEE, neon tubes, used oil, batteries, etc.). €800 to € 3,000 per tonne).

• The reusable

For the NGO Health Care Without Harm, which campaigns against the incineration of medical waste, one of the avenues for improvement is to prefer reusable to disposable and single-use plastics. A more sustainable and economical system in the long term, which could also allow establishments to limit equipment shortages such as those currently encountered on masks or gowns. With this same objective, the think tank The Shift Project also defends the idea of supporting the development of the production in France of reusable medical device equipment.

The internalization of DASRI / DASRIA* *treatment*

Infectious and Similar Risky Healthcare Waste

A health establishment can treat its medical waste internally by transforming it into non-hazardous waste using a shredding and sterilization system by the steam called "trivializer". The purchase of such equipment, which costs between 200,000 and 300,000 euros, is quickly amortized, bearing in mind that a hospital with 300 beds, for example, easily arrives at a bill of 100,000 euros per year for the disposal of its infectious waste. A choice made by several health establishments, such as the Limoges University Hospital, which was equipped with four bathers in 2005. An investment of 1.3 million euros has now been amortised since the establishment records "zero cost" for its infectious waste, with 50 neighbouring establishments also paying it a fee to subcontract their own waste (1).

• Innovation

In its Plan for the Transformation of the French Economy (PTEF), the think tank Shift Project advocates for development of "innovative" recycling channels specific to healthcare establishments for disposable objects (collection by an eco-organisation of medicines thanks to an extended producer responsibility sector, industrial solutions for multi-stream plastic collection ...) in order to reduce waste and be part of a circular economy approach.

• Mobilizing the ecosystem

The willingness of a radiologist or a medical imaging department to act is not enough to make an establishment part of a dynamic of progress. This is only possible by involving all stakeholders : management, buyers, pharmacies, teams. The same applies at the national level to the medical imaging sector through long-term work with the authorities

What the law says

The Environmental Code defines two principles for the disposal of hazardous waste :

- Producer responsibility :
  « Any person who produces or holds waste in conditions that are likely to produce harmful effects on the soil, flora and fauna, to degrade sites or landscapes, to pollute the air or water, to generate noise and odours and, in general, to harm human health and the environment, is required to ensure or ensure its elimination (...) under conditions suitable for avoiding the said effects » (Art L541- 2). This principle is reaffirmed by the Public Health Code for health establishments that are responsible for Healthcare Waste until its final treatment (art R 1335 – 2).

• The "polluter pays" principle It is the responsibility of the producer of the waste to implement a satisfactory solution for its disposal (Art L110-1). Waste of all kinds, but also SAR and medical waste in particular, are also subject to many other regulations (Health Code, Environmental Code, Labour Code, Energy Transition Law...) for nearly fifty years, the objective of which is to reduce their impact on the environment and the risks they represent for health.

In the event of an offence, the criminal liability of an establishment may be incurred for « serious breach of safety and care obligations » et « mise en danger de la vie d'autrui ».

Focus on DASRI and DASRIA medical waste

Déchets d'Activités de Soins à Risques Infectieux* et Assimilés**
Infectious* and Similar** Risky Healthcare Waste

Infectious and Similar Risky Healthcare Waste (DASRI) are waste from diagnostic, monitoring and preventive, curative and palliative treatment activities. Waste that presents an infectious risk because it contains viable micro-organisms, or their toxins, which are known or have good reason to believe that due to their nature, quantity or metabolism, present a health risk are considered to be waste. They bring together many types of waste : waste soiled by blood or infectious biological secretions ; or sharp objects, Devices containing a blood derivative or biological sample, drainage and suction devices, arterial and venous catheters and extenders, chemotherapy care equipment, anatomical waste, bacteriology filters (hood, psm). In imaging, some waste is radioactive waste: soiled waste by blood from patients during the injection of a radiopharmaceutical product and waste soiled by secretions from patients who have recently undergone a nuclear medicine scan.

Contamination by blood or secretions that do not contain an infectious agent (as defined in DASRIA), and this, in small quantities (generally less than 1 litre) does not constitute waste with an infectious risk and must be treated as household waste. It is the psycho-emotional aspect that potentially leads to poor sorting, with oversorting towards the DASRIA.

The Public Health Code states that DASRIA must be sorted at source and treated through appropriate channels. The national average quantity of medical waste produced by a health establishment is 1 kg/bed/day. 15% of medical waste is disinfected, 85 % is incinerated.

waste treatment sectors, industrialists, other disciplines and purchasing groups.
Here too, eco-responsible solutions must take into account the existing territorial organization (which should be disseminated and better known) and the short circuits possible with local establishments and practices, to pool services and collaborations with local recycling actors, and associations in addition to local VEOLIA agencies and other collectors. Collaboration with ADEME and its regional agencies could be envisaged as an aid to structuring and valorization.

(1) Source " The incineration of medicinal waste is progressing and, with it, the emission of toxic products ", Le Monde, May, 15, 2020

Chapter written with the contribution of Mathilde Tillaux, Radiologist in cabinet and clinic in Caen, Audrey Fohlen, Hospital Practitioner in the Uro-digestive and Interventional Radiology sector at the University Hospital of Caen and François Gracia, Engineer at the University Hospital of Montpellier, teacher at the IAE Paris 1 Panthéon Sorbonne - ESQESE Master 2 Manager QS.

10 keys to creating internal dynamics

1. Involve management and the various sectors: care, technical, medico-technical, logistical and administrative
2. Define a waste reduction and management policy within the establishment
3. Identify local relays : the waste referent and managers
4. Provide material means for sorting : trolley, premises, containers, etc.
5. Define simple sorting protocols and best practices
6. Inform, explain, make people understand through a variety of adapted media
7. Regularly train day and night teams, managers, doctors, nursing and medical staff, logistics staff, etc. and take into account the turnover, temporary staff
8. Put the information in the right place (and identify it), for example in the treatment rooms, at the level of the bags...
9. Monitoring the results, the weight of the waste produced
10. Understand mistakes and dismantle misconceptions!

(Source: ARS Bourgogne Franche-Comté)

Annexes

Eco-responsibility in Medical Imaging: the view of our French-speaking colleagues

The issue of eco-responsibility is mobilizing Belgian, Canadian and Swiss radiologists, as evidenced by the articles below written on the occasion of the JFR 2021.

Eco-responsibility in Medical Imaging: the Belgian situation

Doctor Christian Delcour

Medical Imaging Department, Charleroi University Hospital

Belgium is a federal state of 11 million inhabitants, with three national languages (Dutch 60% of the population, French 40% and German 80,000) and 9 ministers responsible for health.

Under these conditions, the coordination of action plans is complex and eco-responsibility in medicine is clearly not a current priority, the only mention on the Ministry of Health's website dates back a few years! Reducing the ecological impact of health care is a public health issue, a moral but also an economic imperative.

At the level of medical imaging, no national initiative exists, only spontaneous local initiatives are hoped for... In our institution (Charleroi University Hospital) we have decided to make it an institutional priority and the imaging department will be a driving force in this project.

Health care is responsible for about 5% of national CO^2 emissions. The main areas of CO_2 savings are well known: reduction of electricity consumption (complex balance because by closing nuclear power plants in Belgium, electricity once again becomes an important source of CO^2 production), reduction of consumables and therefore waste, promotion of responsible purchasing.

The reduction of the electricity consumption of a radiology department is based on an analysis of the consumption of the various tools used and the way in which they are used.
This requires a change in habits: turning on machines only during periods of use, switching off computers/workstations according to the same logic. Air conditioning is a major item that is poorly controlled.

Over the last twenty years, digitization has made it possible to disappear paper documents, film, CDs, etc. but at the same time the number of imaging examinations has continued to increase ! This digitization has a significant ecological cost. Each archived image consumes energy, just as each click on the intranet, the extranet, the internet is not trivial. Cloud storage involves power-hungry servers.
The long-term storage of images and other documents is partly due to certain legal obligations (sometimes more than 30 years of archiving). This obsolete legislation must be adapted.
The energy consumption of an MRI represents that of several hundred European-type households, but it must be admitted that in a specification

for the purchase of an MRI, its ecological footprint is not one of the main criteria of choice for radiologists (nor as a selling point!)

Waste management is also a challenge. 40 years ago, angioplasty balloons were sterilized several times without a second thought. Currently, we are witnessing an overconsumption of single-use equipment, most often manufactured tens of thousands of kilometers away. Recycling of recoverable waste must be implemented (e.g. glass for contrast bottles, metal guides, packaging).

The establishment of this culture of sustainable development will take a long time (involving staff training) because it implies an always difficult change in habits, legislation, hospital management, etc…
As far as imaging is concerned, as a first step, the first step to take, without changing the infrastructure of our services, is to do away with unusual examinations (and wink to eliminate our consumption of meat from another hemisphere !).

Radiology and Environmental Responsibility: The Canadian Perspective

Gilles Soulez, MD, MSc, FRCPC, FSIR
Full Professor
Dpt of Radiology, Radiation Oncology and Nuclear Medicine, University of Montreal President of the Canadian Association of Radiologists

1. **Awareness of the environmental impact of different modalities when indicating an examination.**
Currently, the choice of an imaging modality is based solely on the clinical indication, the performance of the examination and its economic impact. The ecological impact must now be taken into account in the decision, especially when clinical performance is similar. In this context, ultrasound has a significantly smaller carbon footprint. For example, if a follow-up of chronic liver disease is done by ultrasound rather than MRI, this represents a saving of 283 kWh per patient (3).

2. **Optimization of equipment operating times, imaging and reading consoles**
It appears that most imaging equipment and reading consoles are in active mode during long periods of inactivity. The same applies to air conditioning systems in spaces that are not in operation. The operation on a 24-hour basis would maximize the use of the equipment and reduce the carbon footprint (4). The automatic pause of playback consoles and computers after a period of one hour of inactivity would significantly reduce the carbon footprint. In a department equipped with 43 computers and 27 PACS stations, the automatic pause of equipment after one hour of inactivity would save emissions equivalent to 10 cars (5).

3. **Pay attention to the volume of data and maximize server utilization** An Irish study showed that the growth in data volume was 23 % per year, mainly related to TC6. The carbon footprint of data centers around the world could soon be equivalent to the carbon footprint of the aviation sector (6). This is likely to get even worse with the advent of artificial intelligence. It is therefore necessary to be aware of the impact of the volume of data and continue to optimize our examinations to obtain the required clinical information with the minimum of acquisition or reconstruction sequences and sometimes to use artificial intelligence in this optimization exercise. The use of cloud computing rather than local servers would reduce the carbon footprint by 70% for small and medium-sized businesses (7).

4. **The use of consumables and interventional radiology**
An interventional radiology department in the United States estimated that one week of activity resulted in the emission of 23,500 kg CO2, the equivalent of 9,990 litres of gasoline. Half (49%) was related to air conditioning and the electrical consumption of equipment. The second source was the use of single-use equipment (41%). We need to rethink the packaging and recycling of medical supplies that generate a lot of waste.

5. **Minimize the movement of patients and medical staff**
A first sorting - The exams are sent

to a referring hospital that offers 24/7 remote coverage and will send back a report. To carry out a tomo-densitometric examination, 1,500 to 2,000 km of air transport is currently required. The implementation of scanners in the territories of the far north remains a challenge because there is also a great distance between indigenous villages. Recruiting qualified personnel (Radiographers) to operate imaging equipment is also a challenge. The training of independent technologists, particularly in ultrasound, is a necessity. Outside of Indigenous territories, teleradiology now makes it possible to cover several hospital centres remotely and can reduce the radiologist's travel to remote areas. However, here again, the right balance must be found so as not to sacrifice the human contact and multidisciplinary work that is essential to a quality practice. These teleradiological solutions must also integrate easy access with the electronic file, referring physicians and treating teams. Finally, a user-friendly appointment scheduling policy accessible via the web with interoperability for appointment bookings in other specialties makes it possible to synchronize imaging examinations with the various medical visits. This not only reduces the carbon footprint but significantly improves the quality of service to patients.

In conclusion, there is a lot to be done to improve the carbon footprint of our medical imaging care on a daily basis. It is imperative that our community is aware of this and mobilizes now to transform our practice and move it towards carbon neutrality. Canada, because of its large size of territory, must be innovative in order to integrate into a colaboratif network remote areas with urban centres to provide quality service that respects the environment.

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Radiology and Eco-responsibility: we have changed irradiation for patients, we can contribute to reducing the impact of climate change

Salah D. Qanadli,
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The health system, through its structures, needs and developments, is one of the targets where short-term priority actions must be carried out as part of an eco-responsible exercise. Radiology and radiologists in this system occupy a special place for two reasons :

The first reason is that, unfortunately, we have an important responsibility
Data from the Yale University School of Medicine shows that 10% of carbon emissions and 9% of greenhouse gases come from the U.S. health care system! This is not unique to the United States of America and is probably true in all industrialized countries.
Radiology is unfortunately an important contributor. In a study conducted at the University Hospital of Basel, Switzerland, equipped with 3 scanners and 4 MRIs, the energy consumption attributed to radiology represents 4 % of the hospital's total annual energy consumption. This consumption corresponds to the consumption of 852 people living in the city of Basel. In the United Arab Emirates , researchers calculated, more specifically, the production of greenhouse gases resulting from a week's work in an interventional radiology (IR) department and estimated it to be equivalent to the production generated by a vehicle that traveled 95,000 km !
The impact of radiology and IR activities is mainly related to energy consumption (machines, air conditioning and lighting) and the use of single-use devices.

The second reason is that, very quickly, we can act effectively Several actions can be implemented quickly and efficiently :
• A change in the radiologist's practice : including the "energy saving and eco-responsible management" dimensions in the decision-making scheme of radiology examinations alongside the traditional factors of diagnostic performance, risk/benefit and cost-effectiveness. For example, ultrasound examinations, which consume less energy, would be even better placed to serve as a first line of investigation.
• A change in the practice of partners : optimizing the energy consumption of machines. For example, at the hospital in Basel, Switzerland, measurements showed that 1/3 of CT scan consumption and 2/3 of MRI consumption occurred when the machines were not working. It is therefore useful to optimize operation by introducing a standby state of the machines, for example.
• A change in the practice of institutions : optimizing the energy consumption of air conditioning installations and the image archiving and transmission system as well as its access by adopting, for example, 24-hour operational cycles. This optimisation has enabled the Centre Hospitalier Universitaire Vaudois (CHUV) in Lausanne to reduce its electricity consumption over the past five years, while the hospital's activity has continued to increase.
1. A strategic change in institutions :

promoting clean energy. In 2019, the installation of photovoltaic panels in some of the CHUV buildings resulted in CO2 emission savings equivalent to that of 234 cars each travelling 15,000 km. It is also necessary to adopt an eco-responsible purchasing and partnership policy.

• Promoting the concept of the "Green Hospital» : in addition to actions focused on radiology, the radiological community must also integrate the global concept of eco-responsibility in the field of health, which includes many other actions including waste management, adaptation of working conditions, employee mobility and business travel, a carbon offset policy, and the commitment of the State, Educational information for patients. The Swiss national research project "Green Hospital" (NRP73) is fully in line with this dynamic. In addition, surveys and studies in recent years in Switzerland and the United Kingdom have shown that more than 90% of patients and citizens adhere to the concept of eco-responsibility in the field of health.

If eco-responsibility is everyone's business, the radiologist , through his practice and the infrastructures linked to it, is in a position that allows him to play an important role in the actions to be carried out in the short term. The radiologist and his care and industrial partners are certainly the best advocates of rapid, visible and quantifiable change to contain, if not prevent, the impact of climate change.

SNITEM Contribution

The future of imaging equipment: the eco-responsibility challenges of today and tomorrow

Global climate challenges are becoming more pressing, and industry and healthcare players are striving limit the temperature increase to below 2°C.

In this context, the UN has issued recommendations that manufacturers can draw inspiration from for sustainable and responsible access to care. These recommendations include goals that address health and the well-being of all, but also on sustainable consumption and production patterns and the fight against climate change.

This advice has been heard and taken into consideration by the medical imaging industry and their suppliers, who comply with all laws and regulations concerning the environment, such as the international standard for environmental management ISO 14001 and some even stricter standards that take into account their impact on the environment and biodiversity in general.

This text specifies the objectives and actions of the medical imaging manufacturers gathered within the National Union of the Medical Technology Industry (SNITEM) to reduce the environmental impact of their products and commercial processes.

1 Reduce resource consumption In the environmental field, the definition of the main eco-responsibility issues of industry players starts with the assessment of the life cycle of products in order to determine the environmental impact at each stage, from the extraction of the raw material to the transformation of materials, manufacturing, distribution, use, repair and maintenance, including disposal or recycling.

COCIR - the European association representing the medical imaging, radiotherapy, health ICT and electromedical industries, has highlighted that it is the energy consumption during the use phase and the lifetime of the product that represents the most important part of the environmental impact of medical imaging devices.

All manufacturers have concentrated their developments on technological innovations to reduce irradiation and shorten examination times. In addition to the benefit for the patient, these solutions are now more suitable and significantly reduce the power consumption and power required for the proper functioning of the systems.

Manufacturers offer solutions to reduce power consumption for heavy imaging modalities, such as scanners and MRIs, but also for conventional radiology. Innovations in optimised system management can in some cases reduce electricity consumption by 25 to 40%, as already proposed by the automotive industry with the "stop and start" of motors or hybrid technologieswith the use of batteries.

Another example, to cool the magnet, the MRI model consumes helium, a fossil resource, recovered during the extraction of hydrocarbons that could be depleted by 2035 (1). The principles of eco-design apply here with the reduction of the number of liters of helium and also the non-consumption of helium during the operating life of the systems (Zero Boil Off Technology). Most conventional MRIs contain 1,500 to 2000 liters of helium, a figure that can be reduced to seven for some systems.
The recent development of new technologies based on Artificial Intelligence makes it possible to improve the quality of images and to help detect patients at risk and prioritize them. Deep learning applications secure the diagnosis and management of patients and thus offer more efficiency and optimized use of imaging modalities.

Ecodesign processes therefore focus on this issue, but also on other priority areas of action to improve the environmental performance of our products : packaging, substances, weight, materials, shelf life and circularity.
In addition to eco-design principles and product development, manufacturers are also working to reduce the environmental impact of emissions from industrial sites (manufacturing and assembly sites), non-industrial sites (offices, warehouses, computer centres and R&D facilities)), business travel (car and plane rental), logistics (air, sea and road transport).

Waste management policy in a company at all its sites
Beyond the reduction of resource consumption, the real challenge of eco-responsibility for manufacturers consists above all in decoupling economic growth from the use of natural resources through more efficient use of these resources, in a process of transition from a so-called linear economy to a circular economy.
Replacing the use of material resources with digital solutions is part of the transition to a circular economy, in particular by reducing material needs, but this is not enough. Manufacturers are thus committed to the development of solutions to optimize the use of resources, to support the digitalization of health.

2 Sustainable development of our suppliers
The complexity of value chains in the medical device industry leads manufacturers to work with millions of product and component suppliers and service providers.
It is therefore necessary for manufacturers to develop sustainable development programmes with their suppliers across supply chains. These programs cover strict compliance with the various policies put in place by manufacturers, in the field of mineral supply for example, but also the reduction of their environmental impact and, more broadly, the improvement of suppliers' performance in terms of sustainable development.

Improve supplier sustainability performance : To ensure the implementation of such programs, manufacturers have been moving away for several years from the traditional approach of auditing suppliers, which is often considered insufficient to lead to sustainable improvements.
New and more effective approaches

since then have been focused on :

- Systematization of the approach to improving the sustainability of supply chains
- Continuous improvement in relation to a set of recognized and global references
- Collaboration, increased transparency, clear commitments, and ensuring suppliers meet agreed goals
- Encouraging suppliers, peers in our industry, and peers in other industries to adopt our approach.

Responsible Sourcing

A key area of industrial action in terms of sustainable supplier performance is the responsible sourcing of minerals. Indeed, the medical device industry requires a substantial supply of minerals and there are generally more than 7 levels between end-user companies and the mines where minerals are extracted.

The extraction of these minerals can take place in conflict-affected areas, where mining is often informal and unregulated and takes place in artisanal small-scale mines (ASM). It is observed that these ASMs are vulnerable to exploitation by armed groups and local traders. In this context, there is a risk of serious human rights violations (forced labour, child labour or widespread sexual violence), unsafe working conditions or environmental concerns.

Manufacturers therefore require continuous due diligence processes by their suppliers in this area, combined with active participation in multi-stakeholder initiatives to promote responsible sourcing of minerals.

2 Reduction of the environmental impact of suppliers

Manufacturers are also taking action through third-party sustainability programs in supply chains, such as the Carbon Disclosure Project (CDP), which encourages suppliers to disclose their environmental performance, promotes board responsibility for climate change, and actively works on emission reduction initiatives. Through CDP, suppliers to one of the manufacturers undertook projects that resulted in carbon emission savings of 62 million metric tons of CO2 in 2019.

Reduction of the environmental impact of transport

Manufacturers work with their transport providers to reduce the environmental impact of transporting products, by choosing ISO (ISO-14001) certified transport companies that comply with local laws and regulations. In addition, most road transport service providers have set up their own programmes to reduce fuel consumption, train drivers in eco-driving, optimise the network, upgrade the existing fleet to save energy, etc.

Manufacturers are also working to reduce the use of air freight. By favouring sea or rail routes rather than air, it is possible to generate up to 55 times less CO_2 emissions per shipment.

In addition to the modes of transport chosen, manufacturers are also working to reduce the environmental impact of transport by reducing the weight of products (less CO2 emissions) making them less bulky and more integrated and packaging products more efficiently (more products in one truck),

consolidating freight to optimize load and switching to an environmentally friendly mode of transportation where possible. For example, for one manufacturer, the adoption of a new packaging process saved 1 hectare of forest per year and a 20 % reduction in CO2 emissions per installed system.
Old process : wooden packaging New process : innovative cardboard packaging
Another example of a packaging procedure for an X-ray table : filmed packaging known as "mover mode", without a wooden crate, on a metal pallet recovered from delivery

3 From a linear economy to a circular economy
A circular economy aims to decouple economic growth from the use of natural resources through a more efficient use of these resources.

Recycling of medical devices and equipment
Mandatory for all European manufacturers, REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) is a regulation of the European Parliament and the Council of the European Union, adopted in 2006, which modernises European legislation on chemical substances, and establishes a single integrated system for the registration, evaluation and authorisation of chemical substances in the European Union. Manufacturers must ensure that the components they use meet this standard.
The European RoHS Directive (2002/95/EC) (Restriction of Hazardous Substances in electrical and electronic equipment) aims to limit the use of six hazardous substances in electrical equipment and electronic systems.
Directive 2002/96/EC of 27 January 2003 (2) stipulates that the presence of hazardous components in electrical and electronic equipment (EEE) poses a major problem during the waste management phase and assigns responsibility to the producer, on the polluter-pays principle. It encourages the recycling, reuse and reclamation of waste electrical and electronic equipment.
WEEE Treatment (Electrical and Electronic Equipment Treatment) Sequence of operations to decontaminate WEEE, separate the different fractions of constituent materials and recover them in the manufacture of new products.
As a result, manufacturers of heavy imaging equipment have become active in the cycle of resumption, reconditioning and reuse of their systems. To help consumers adopt these trade-in channels, loyalty programs or trade-in bonuses are offered by most manufacturers. These initiatives are supported by market players, in particular by the Fédération Hospitalière de France (FHF) which in its white paper on ecology (3) encourages limiting waste generation and adopting a circular economy.

The reconditioning of systems is therefore offered by manufacturers, but also by third-party companies. However, the warranty conditions following this reconditioning and the question of compliance with French and European standards arise. Indeed, the term "refurbished" does not commit to anything and each company has its own charter as to the tests to be carried out and the parts to be changed. In this context, caution should be exercised regarding the delegation of operations

reconditioning to third-party companies rather than to the manufacturer.
Some manufacturers are committed to taking back 100 % of their heavy equipment in 2020 to be reconditioned or recycled.

System scalability
There are several advantages to promoting the scalability of machines : their transformation costs fewer environmental and financial resources. For example, to enhance its clinical capabilities, imaging equipment may be equipped with licenses for new software, or a subscription with a schedule of continuous improvements. Many subscriptions currently exist among manufacturers, to allow customers to access the latest level of innovation as soon as it is available, regardless of the year of acquisition of their system.
One of the key principles of the circular economy is to maintain the highest possible level of value at all times in a product's life cycle. Transitioning from a model based on selling products to one based on service and value for consumers improves the consumer experience while limiting waste.

Conclusion
The reduction of resource costs is promoted by technological innovation, from the design phase through product life cycle analysis and eco-design, to reduce the consumption of energy and raw materials of the equipment and the sites that produce them.

Companies also require their suppliers and distributors to respect their charters and commitments for ecology, to achieve significant impact ; This is reflected in the adoption of a quality approach in accordance with these principles and the limitation of emissions through supply and transport.

Finally, the circular economy is making its way into the process of taking back and recycling electrical and electronic devices by suppliers, ensuring a second life for products or at least recovering waste, and the creation of scalable systems and solutions to move away from a linear "single-use" consumption pattern.

1) https://www.mediatheque.lindau-nobel.org/videos/31360/the-looming-world-shortage-of-helium-lecture-discussion-2010/laureate-richardson2)

2) https://eur-lex.europa.eu/resource.html?uri=cellar:ac89e64f-a4a5-4c13-8d96-1fd1d6bcaa49.0007.02/DOC_1&format=PDF

3) http://v.calameo.com/?bkcode=0037957026c11c4f5eb72

The Collectif Écoresponsabilité en santé (Ceres): Interdisciplinary mobilization in favor of eco-responsibility

Several scientific scieties and professional associations (1) joined forces at the end of 2020 to create a Collective for Eco-Responsibility in Health (Ceres) whose objective is to make the world of health aware of its role and its Involvement in sustainable development.

Ceres aims to bring together a "pluralist, transversal, interdisciplinary, interprofessional group involving all the actors of the health system, including patients". "It is paradoxical to note that the sector where we are most concerned about people's health, namely the health system, is also the one where ecological concerns have little place in the world". Through the creation of this group, which SFR has joined, "It is about making the world of health aware of its role and involvement in sustainable development in order to improve public health and mitigate climate change and its effects on health".

Several scientific scieties have taken an interest in and become involved in eco-responsibility projects in health in recent years, the founders point out, before adding : "However, it seems to us, without ignoring the work accomplished, that this subject goes beyond the framework of specialized societies and must involve all the actors of the health system. Climate targets cannot be achieved without systemic transformation on a collective scale".

Ceres' objectives and missions

- To spread the concept and culture of eco-responsibility in health in the community of caregivers in the broadest sense
- Promote the need for the implementation of eco-responsible action plans within the health system
- Integrate eco-responsibility into the broader framework of sustainable development, which is not limited to the environmental aspect but also integrates the economic and human aspects
- Promote collaboration between different specialties and trades involved in sustainable development (list the different initiatives and network the actors)
- To make available to the various actors the means to implement eco-responsibility and sustainable development protocols (recommendations, models, circuits, tools)
- Implement sustainable development actions/programmes and organise scientific meetings

- Work on the development of an eco-label for establishments that will develop a program according to specifications

- To act as a relay and collaborate with supervisory bodies and official bodies to promote and structure the sustainable development approach in health

- Participate in and develop initial and continuing training on sustainable development in health (DU)

- To help develop research in the field of health ecology.

(1) French Association of Surgery (AFC), French Society of Anaesthesia and Rehabilitation (SFAR), French-speaking Group for Enhanced Rehabilitation after Surgery (Grace), French Society of Clinical Pharmacy (SFPC), French Society of Hospital Hygiene (SF2H), France Assos Santé, Association of Young Visceral Surgeons (AJCV), National Union of State-Certified Operating Room Nurses' Associations (Unaibode), National Professional Council of Nurse Anaesthetists (CNP-IA), e-Health Council.

The "learning" radiologist

The SFR has proposed recommendations for a more eco-responsible practice to the radiologists attending the conference in the use of their tools (computers, smartphones) which also apply to the professional daily management of radiology.

The proper use of digital technology: 10 common sense rules

Use power strips with a switch Most of your electronic devices are permanently connected to a power outlet. Even if this equipment is on standby, it consumes a small amount of electrical current which can represent a significant consumption over time. For a household, all your appliances on standby represent an average power of more than 50 watts according to Ademe. In other words, eliminating the monitoring system saves about 80 euros per year.

Good to know!
Simply use a power strip with a switch to avoid this unnecessary residual consumption.

Archive and empty your email inbox
An e-mail with an attachment of a megabyte emits 20 g of CO_2 into the atmosphere, which is equivalent to the electricity consumption of a 60 W light bulb for 25 minutes. However, 80 % of emails are not opened.
– For large files, prefer sending services with short retrieval times : WeTransfer, Smash, Lufi, etc. This helps to limit storage time.

– Organize your emails and make an archive on a removable hard drive

– Remember to empty the trash of your email inbox

Fight against planned obsolescence You don't have to replace your smartphone every year. Their technology is mature and the functional contributions are rather on the software part. After 2 or 3 years, the autonomy of your phone decreases : you can have its battery replaced to give it a new lease of life and extend its life. The most environmentally friendly material is the one that cannot be replaced.

Type the URL in the search bar and use the "favorites" function
When the user uses a search engine, the data center first delivers the home page. Then the user writes a keyword query, then the data center sends the results found. Sitôt que l'utilisateur clique sur ce qui l'intéresse, The data center of the host of the selected site transmits the web page.

Good to know!
By typing the URL of the site directly into the search bar, we simplify the process of operations and reduce the carbon footprint of a search.

Delete unused mobile apps
Even if it is no longer used, an installed application continues to use the phone's resources and to generate automatic updates. Deleting these apps avoids consuming power for no reason and saves memory.

Remove unnecessary software
Installed by default on new computers,

some software is of no interest to the user. Don't hesitate to uninstall them as they can slow down your entire system and reduce the lifespan of your equipment.

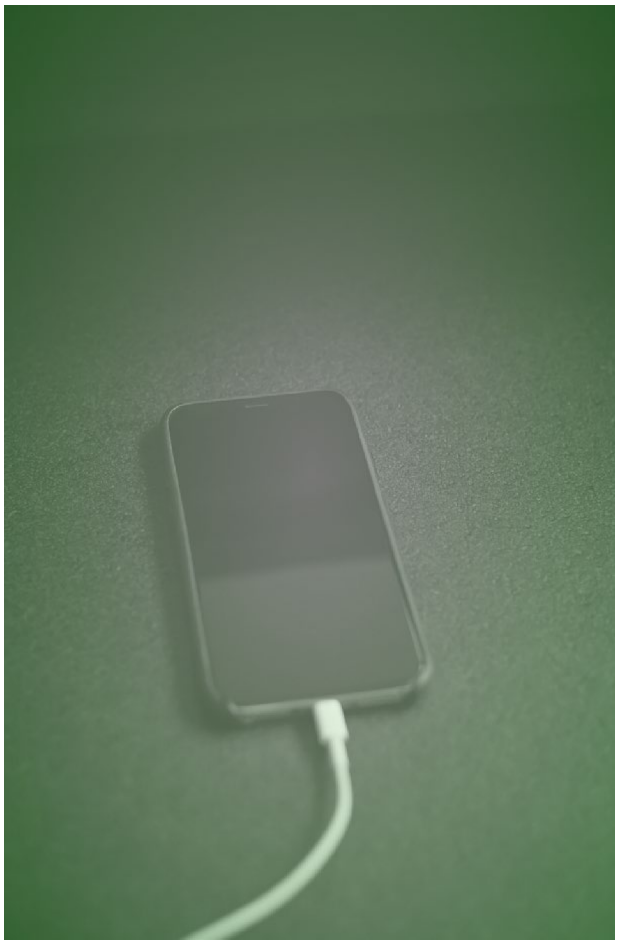
Close your inactive tabs
You thought that the 15 tabs you opened on your browser did not consume power ? Mistake, they constantly communicate and send information. Remember to close them and use favorites to come back to them more easily.

Store your files locally
Online storage (emails, photos, videos, office documents, etc.) generates incessant back-and-forth between the user's terminal and the servers. Transporting data via the internet consumes twice as much energy as storing it for a year. It is therefore necessary to promote storage as much as possible. Once unplugged from your computer, a hard drive will not consume power. This is the best way to secure your digital documents in a cost-effective way.

Reduce your smartphone's power consumption.
Once charging is complete, it is important to unplug the electronic device as it continues to consume. This will save you 10 % on electricity.

Decrease the brightness of your devices to charge them less often and to extend battery life. If you don't use it at the moment, turn off WIFI, Bluetooth, location and 4G and you will increase your battery life. Remember to close all open applications at the bottom of the task for they consume energy and memory. **Turn off unnecessary notifications** Many apps continuously solicit users with prompt notifications. Disabling or setting notifications avoids generating unwanted queries. It is also a good way to disconnect when you spend too much time on your smartphone : it reduces the mental load.

Good to know!
Smartphones are equipped with a "Do Not Disturb" that you can activate during the time slots of your choice. This will have the effect of cutting off all the notifications of your smartphone.



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