Sustainability and Climate Protection in Radiology – An Overview

Nachhaltigkeit und Klimaschutz in der Radiologie – Ein Überblick

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ABSTRACT

Background Sustainability is becoming increasingly important in radiology. Besides climate protection – economic, ecological, and social aspects are integral elements of sustainability. An overview of the scientific background of the sustainability and environmental impact of radiology as well as possibilities for future concepts for more sustainable diagnostic and interventional radiology are presented below.

The three elements of sustainability:

1. Ecology

With an annually increasing number of tomographic images, Germany is in one of the leading positions worldwide in a per capita comparison. The energy consumption of an MRI system is comparable to 26 four-person households annually. CT and MRI together make a significant contribution to the overall energy consumption of a hospital. In particular, the energy consumption in the idle or inactive state is responsible for a relevant proportion.

2. Economy

A critical assessment of the indications for radiological imaging is important not only because of radiation protection, but also in terms of sustainability and “value-based radiology”. As part of the “Choosing Wisely” initiative, a total of 600 recommendations for avoiding unnecessary examinations were compiled from various medical societies, including specific indications in radiological diagnostics.

3. Social Sustainability

The alignment of radiology to the needs of patients and referring physicians is a core aspect of the social component of sustainability. Likewise, ensuring employee loyalty by supporting and maintaining motivation, well-being, and job satisfaction is an essential aspect of social sustainability. In addition, sustainable concepts are of relevance in teaching and research, such as the educational curriculum for residents in radiology, RADUCATION or the recommendations of the International Committee of Medical Journal Editors.

Key points

- Sustainability comprises three pillars: economy, ecology and the social component.
- Radiologies have a high optimization potential due to a significant demand of these resources.
- A dialogue between medicine, politics and industry is necessary for a sustainable radiology.
- The discourse, knowledge transfer and public communication of recommendations are part of the sustainability network of the German Roentgen Society (DRG).

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ZUSAMMENFASSUNG

Hintergrund Nachhaltigkeit gewinnt in der Radiologie zunehmend an Bedeutung. Diese geht über den Klimaschutz hinaus – insbesondere die Ökonomie, Ökologie und soziale Komponente sind zentrale Elemente. Ein Auszug aus der Studienlage über den Status Quo sowie mögliche Ansatzpunkte für Konzepte einer zukünftig nachhaltigeren Hochleistungsmedizin in der Radiologie werden im Folgenden dargelegt.

Die Drei Säulen der Nachhaltigkeit:

1. Ökologie

Mit weiterhin jährlich wachsender Anzahl an Schnittbildgebungen steht Deutschland im Pro-Kopf-Vergleich weltweit an einer der führenden Positionen. Ein MRT verbraucht jährlich ca. eine äquivalente Menge Energie wie 26 4-Personenhaushalte. Allein die Großgeräte CT und MRT tragen somit signifikant zum Gesamtenergieverbrauch des Krankenhauses bei. Hierbei macht insbesondere der Energieverbrauch im Ruhe- oder Inaktivitätszustand einen relevanten Anteil aus.

2. Ökonomie

Eine kritische Indikationsprüfung radiologischer Bildgebung ist nicht nur aufgrund des Strahlenschutzes, sondern auch im Sinne der Nachhaltigkeit und “value-based radiology” bedeutend. In Rahmen der “Choosing Wisely”-Initiative wurden deshalb aus verschiedenen medizinischen Fachgesellschaften insgesamt 600 Empfehlungen zum Verzicht auf nicht notwendige Untersuchungen zusammengetragen, unter anderem auch für spezifische Indikationen der radiologischen Diagnostik.

3. Soziale Komponente

Die Ausrichtung radiologischer Tätigkeit auf die Bedürfnisse von Patientinnen und Patienten sowie Zuweisenden ist ein Kernaspekt der sozialen Komponente von Nachhaltigkeit. Ebenso stellt Mitarbeiterbindung über Förderung und Erhalt der Motivation, des Wohlbefindens sowie der Arbeitszufriedenheit einen essenziellen Aspekt sozialer Nachhaltigkeit dar. Darüber hinaus sind in der Lehre und Forschung nachhaltige Konzepte, wie durch das Weiterbildungscurriculum Radiologie, RADUCATION oder die Empfehlungen des International Committee of Medical Journal Editors von Relevanz.

Introduction

Is it possible to combine radiology with sustainability and climate protection? The importance of sustainability and climate protection in radiology was highlighted at the 103 rd German X-ray Congress with the title “Live diversity – shape the future”. In spite of awareness of the need for sustainability and climate protection, these concepts are currently met with ambivalence in the face of numerous marketing campaigns, economic “greenwashing”, and demonstrations by the “last generation”. To allow a thematic differentiation from the sometimes negative perception of these concepts, a dedicated, systematic, and scientific examination of sustainability and climate protection in radiology is needed.

Radiology as a technology-based field with high energy consumption has a particular responsibility regarding climate protection. Maximum care and high-performance medicine require significant resources. The high energy consumption of large equipment is significant both environmentally and economically due to the massive increase in energy prices.

Current studies and initiatives like “Health for Future” have shown that the health care industry accounts for a substantial percentage of global CO_2-equivalent emissions and thus plays a role in climate change. The number of examinations performed in radiology increases each year. In 2019, approx. 24 million cross-sectional imaging examinations were performed in Germany, with approximately half being CT examinations and half being MRI examinations [1, 2] Germany is one of the leading countries worldwide with respect to the number of MRI examinations performed per 1000 inhabitants. 145 examinations were performed per 1000 inhabitants in Germany in 2019, thus putting Germany in second place behind the United States. Moreover, this value is almost twice as high as the average number of examinations performed in the 30 OECD (Organization for Economic Cooperation and Development) countries (79 per 1000 inhabitants) [2].

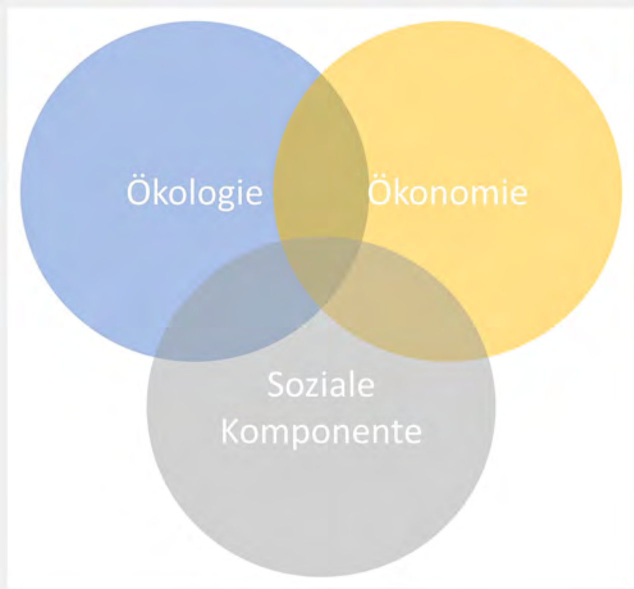
To ensure that the term “sustainability” is used correctly in the following, the etymology and meaning must first be discussed. The term was originally primarily used in forestry: do not cut more wood than will grow back [3]. Today, sustainability is viewed as a generalized maxim based on longevity and future-oriented behaviors. There are various definitions of sustainability. One commonly used term is the “three pillar model” which differentiates between three essential elements (▶ **Fig. 1**): Ecological, economic, and social aspects [4]. These core areas include not only energy-related aspects but also value-based radiology, future-oriented training and research, and a sustainable relationship to patients, referring physicians, and colleagues in radiology.

The following provides an overview of the current literature on these often overlapping core aspects of sustainability in radiology and discusses various possibilities for optimization.

The three elements of sustainability

Environment

The EU, the USA, China, and India are the leading producers of greenhouse gases, which are a major contributor to climate change [5, 6]. In spite of efforts to achieve the climate goal of net zero emissions by 2045, a global increase in emissions of 6 %, i. e., an increase of two billion tons to approx. 36.3 billion, the greatest increase to date, was recorded in 2021 [7]. According to



▶ **Fig. 1** Core aspects of sustainability.

projections for 2022, the annual total emissions increased by an additional 1 % compared to the previous year. The resumption of international flights is partly responsible for this increase. However, in 2019, according to the climate report by "Health Care without Harm", the emissions of the health care sector were still higher than that of the aviation industry (3 %) and the marine industry (2 %) [8]. The health care industry is responsible for 4.4 % of annual greenhouse gas emissions globally and 5.2 % in Germany [9]. The emissions produced by the health care industry in the EU are the third highest in the world after the USA and China. In relation to emissions per capita, the German health care system is one of the world's major emitters, with 1–0.5 t/person [9, 10].

The energy consumed by large radiology equipment makes up a significant percentage of the total energy consumption of hospitals. It is difficult to determine exactly what percentage of the total consumption of hospitals is comprised of energy consumed in radiology since this value depends on the total size of the radiology department and its proportion of the total hospital. T. Heye et al. showed an annual total consumption of 1 107 450 kWh with a corresponding energy cost of $199 341 in 2015 for 4 MRI units and 3 CT scanners [11]. These devices were responsible for 4 % of the total energy consumption of the hospital of 27 905 332 kWh [11]. If equipment not included in this study is also taken into consideration, radiology's percentage of the total energy consumed by the hospital would thus be significantly higher.

Although examinations have the highest peak energy consumption, the time interval between CT examinations in the non-productive idle system state accounts for 2/3 of the total consumption [11]. The continuous energy consumption of most large equipment in the system on state without image acquisition is the reason that a high percentage of the total consumption is comprised of non-productive phases. Moreover, an MRI system in the system off state constitutes approximately 1/3 of the total energy consumption due to the continuous helium cooling [11].

Consequently, there is significant potential for energy conservation with respect to large radiology equipment, particularly CT, MRI, PET-CT, angiography, and hybrid systems like CT/angio and PET-MRI. This equipment should be turned off during unproductive phases at night or on the weekend. Aside from equipment for emergency operation, a possible reduction in equipment consumption of 20–60 % can be achieved depending on operating times and energy consumption when the system is switched off. Devices with lower capacity utilization or longer inactive time intervals during productive operating time, e. g., angiography and fluoroscopy systems, can also be switched off during the day since the time to operational readiness is often less than 5 minutes. Sonography units usually have a standby mode. This should be set with a low time value for automatic activation.

Heye et al. were also able to show that the thermal output of MRI systems is significantly less than the amount of cooling that is supplied so that a majority of the cooling remains unused. Customization by the manufacturer to the energy and building technology of an institute or hospital when configuring the cooling systems, the necessary energy supply, and the humidity and ventilation control in the service rooms provides a further opportunity for energy conservation. Finally, further studies and discussions among hospitals, scientists, and the health care industry will show how the unused idle state and the calculated MRI cooling can be optimized to reduce the energy consumption of large equipment.

Moreover, a positive effect on energy consumption can be achieved by performing critical evaluation of indications and individualized adjustment of examination protocols. Particularly in the case of MRI, any shortening of the examination time with protocol optimization or the use of deep learning sequences results in a reduction of the energy consumption per examination and thus in greater energy efficiency.

Economy

Based on data from the World Health Organization (WHO), an estimated 3.6 billion diagnostic examinations are performed worldwide each year [12]. According to the Federal Office for Radiation Protection, approximately 130 million X-ray procedures and approximately 18 million CT examinations were recorded in 2018 and the figures are increasing [13]. A critical assessment of the necessity of radiological imaging in terms of "how will it change management?" is extremely important not only in terms of radiation protection, determining the individual indication for contrast agent, and diagnostic significance, but also in terms of economy, sustainability, and value-based radiology [14–16]. Value-based radiology is based on the concept of creating added value for patients, the health care system, and society by providing radiology services based on scientific recommendations. One of the key aspects is to reduce volume-based practice and to place the focus primarily on the medical significance and sustainable value of radiology examinations.

In this context medical societies in the USA have been asking their members since 2012 to identify diagnostic tests and medical procedures in their area of expertise whose importance should be examined and discussed [17, 18]. 80 medical societies from 20 countries have published a total of 600 "Choosing Wisely" recommendations for avoiding unindicated tests and treatments.

The American College of Radiology suggested dispensing with the following examinations:

1. The unenhanced phase of abdominal CT with the exception of the workup of hepatic and renal lesions, hematuria, adrenal lesions (unenhanced > 10 HU), postinterventional examinations in suspicion of endoleaks, and a search for the source of bleeding [19–25].
2. Late venous contrast phase in abdominal CT, except in unclear adrenal or renal lesions and hematuria, CT urogram, and suspicion of hepatocellular carcinoma and cholangiocellular carcinoma [20, 22, 26–33].
3. Follow-up examinations in asymptomatic, non-obstructive short-segment small bowel intussusception (≤ 3.5 cm) [34–37].
4. Diagnostic ultrasound in incidental thyroid nodules on CT/MRI, except if malignancy criteria are met and the age-adapted size cut-off values are exceeded or there is lymph node enlargement [38–46].
5. Follow-up in uncomplicated ovarian cysts < 5 cm in premenopausal women or < 3 cm in postmenopausal women [47–51].
6. Preoperative chest radiographs in young patients (< 70 years old) without clinical suspicion of preexisting cardiopulmonary conditions [52–58]
7. CT angiography in suspicion of pulmonary embolism as long as there is a low pretest probability (Wells score < 2) or negative D-dimer test [59–63].
8. Diagnostic radiology in headache without corresponding risk factors or suspicion of a neurological structural defect [64–67].

In addition, the radiology report is the foundation for the further diagnostic-therapeutic cascade. Performing additional unnecessary diagnostic imaging requires personnel and energy and results in an avoidable financial burden for hospitals and patients. For this reason, radiology reports must include precise characterization of pathologies according to established classifications with the associated scientifically proven recommendations (according to Bi-RADS, Ti-RADS, Bosniak criteria, Fleischner criteria, etc.) in This can help to determine whether and when follow-up imaging or further clinical testing is needed or what can be omitted.

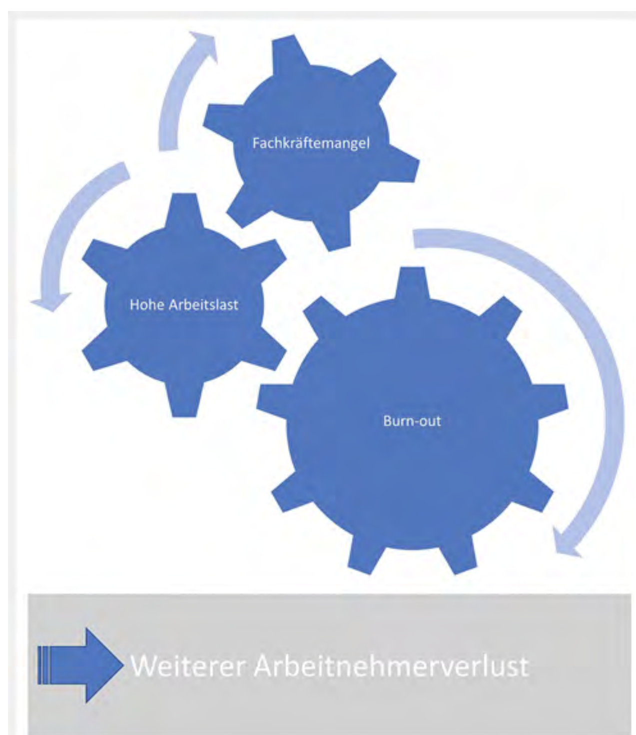
More sustainable medicine, which benefits patients in the long term, helps to improve health care by optimizing resources and also influences the social aspect of sustainability.

Society

The social component of sustainability includes sustainable relationships with patients and referring physicians as well as the acquisition, retention, and motivation of employees and the maintaining of employee well-being and satisfaction. This is even more relevant in light of the fact that there has been a growing staff shortage in radiology for over 20 years and the number of examinations is constantly increasing [68–70]. Radiology is also one of the disciplines with an increased risk of burn-out [71, 72]. Therefore, there is a high prevalence of burn-out predictors already among residents in radiology [73, 74]. In addition to attracting and retaining medical personnel, another current challenge is increasing the attractiveness of a career as a medical technologist for radiology. Thus, the final report of the German Hospital Institute on the "shortage of skilled labor and the need for skilled medical technologists" in 2019 states that 46 % of hospitals have difficulty hiring medical technologists in radiology for open positions (versus 23 % in 2011) [75]. Based on immediate demand, anticipated retirements, and the growing number of cases, an increase to 12,740 full-time medical technologist positions including 52 % medical technologists for radiology can be expected for 2030.

Therefore, sustainably ensuring the job satisfaction and health of medical personnel and medical technologists in radiology is of vital importance for radiology (▶ **Fig. 2**).

Moreover, the social aspects of sustainability include the relationship to patients and referring colleagues as described in a current narrative review by our work group [4]. At present, radiology is valued by most referring physicians. There is improvement potential primarily in the optimization of radiology reports using (partially) structured reporting. Most patients would also like the opportunity to discuss results with the radiologist. However, available studies on patient-centered care are largely limited to the determination of the actual status without providing concrete solutions for the problem of an already high workload and the desire on the part of patients to have closer contact with physicians. Satisfying this wish and being perceived as the primary contact person for patients is of utmost importance due to the expected



▶ **Fig. 2** Vicious cycle of skilled labor shortage and high workload followed by burn-out and additional loss of employees.

integration of artificial intelligence in the daily routine in radiology.

Moreover, the social components of sustainability also relate to radiology teaching in medical school and specialist training. This must be sustainable with respect to acquiring new talent, increasing work satisfaction of residents, and ensuring efficient use of teaching resources. Therefore, radiology residents stated that they benefited from personal supervision of reporting and in particular from structured teaching and fixed rotations [76, 77]. However, as long as specialist training in Germany is not reimbursed, teaching will be based on department-dependent structures and the personal commitment of supervisors. To ensure a long-term and sustainable specialist training structure for trainees and teachers, the Young Radiology Forum together with the work groups of the German Radiological Society, the German Society for Interventional Radiology and Minimally Invasive Therapy, the German Society for Neuroradiology, and the German Society for Pediatric Radiology created the specialist training curriculum for radiology in 2021 [78]. To take advantage of the benefits of the numerous digital teaching platforms that were created in response to the COVID-19 pandemic and can be used in a sustainable, efficient, and location-independent manner, RADUCATION was developed in 2022 [79, 80]. RADUCATION provides a digital education platform with content that is synergistically collected and updated by the specialist training task force of the Young Radiology Forum and is based on the radiology specialist training curriculum [81].

Finally, sustainable concepts in research and science are also of increasing relevance as part of the third element of sustainability. Thus, in 2017, the International Committee of Medical Journal Editors (ICMJE) demanded that the manner in which research data will be made available to the scientific community must be defined during study registration in order to meet the ethical responsibility with respect to study participants [82]. In addition to transparency and control, this allows the sustainable use of generated data for secondary analyses. The ICMJE's requirement to register studies prior to the inclusion of participants in order to avoid a selection bias also supports the sustainable use of resources and the protection of study participants by preventing multiple studies on identical subjects and using identical methods.

Outlook

94 % of patients consider more sustainable hospitals desirable [83]. Sustainability in medicine and radiology is thus becoming increasingly important under consideration of the three pillars: economy, environment, and society. Due to the significant consumption of a variety of resources, not only climate protection but also the health care industry, patients, employees, and science will benefit from future-oriented, sustainable concepts in radiology.

In addition to potential financial savings due to process optimization and reduced energy consumption, corresponding costs for a larger restructuring should also be calculated. With a focus on climate protection, KLIK Green determined during the training of climate managers that a 40 % reduction of emissions can already be achieved with no or minimal investment. In addition to the already mentioned aspects, there are many other possibilities in the daily routine to achieve more sustainable radiology [84]. The 10-point plan of the German Radiological Society provides information about investment-free sustainability recommendations [85].

However, since many aspects of sustainability in radiology have been insufficiently examined to date, the Sustainability Network of the German Radiological Society is engaged in dynamic discussions involving the areas of medicine, politics, and industry in order to advance these processes. The raising of awareness, the exchange of information between science and economy, and the transfer and publication of knowledge are also central components of the network and can be viewed online [86].

The goal is thus to work together with the various authorities to develop future-oriented and sustainable concepts for radiology that will benefit patients, employees, radiology, the health care industry, and the environment equally.

"As for the future, your task is not to foresee it, but to enable it."
Antoine de Saint-Exupèry
(From "The City in the Desert", 2009)

Conflict of Interest

Isabel Molwitz war als Vorsitzende des Forums Junge Radiologie an der Entwicklung des Weiterbildungscurriculums Radiologie sowie von RADUCATION aktiv beteiligt.
Dr. med. Viktoria Palm war als Mitglied des Forums Junge Radiologie bei der inhaltlichen Ausgestaltung von RADUCATION aktiv beteiligt.
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