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Insights on the carbon footprint of radiotherapy in France

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Insights on the carbon footprint of radiotherapy

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Abstract:	<p>The French healthcare system is responsible for 8% of the national footprint. Achieving a net zero emissions scenario will require a 4-5 fold decrease of carbon emissions in the coming years. The carbon footprint of radiation therapy has not been specifically studied to date.</p> <p>In this review we summarize the content of the carbon footprint dedicated session in the SFRO congress. We discuss the French healthcare system carbon footprint and its major drivers and our work on the estimation of the carbon footprint of external beam radiation therapy in the French setting. We developed a dedicated methodology to estimate the carbon footprint related to radiation therapy treatments, and describe the main drivers of emissions based on a single center as an example, namely patient's rides, accelerators acquisition and maintenance and data storage. Based on the carbon footprint calculated in our centers, we propose mitigation strategies and an estimation of their respective potential. Our results may be extrapolated to other occidental settings by adapting emission factors (kgCO₂/item or euro) to other national settings.</p> <p>EBRT has a major carbon footprint that may be mitigated in many ways that may impact how radiation therapy treatments are delivered, as well as the national organization of the radiotherapy sector. This needs to be taken into account when thinking about the future of radiotherapy.</p>

Credit Author Statement

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M.P. conceived the study, elaborated the methodology, wrote and validated the work.

Co.D., B.A., Ch.D. conceived the study, and validated the work.

A.A., C.M., S.R. and J.V. participated to the writing

M.E., M.K. reviewed the manuscript

D.A. analyzed the data and participated to the writing

G.D., S.S. coordinated the writing of the manuscript

Légendes

Figure 1 : Detailed carbon footprint of French hospitals, excluding medication and medical devices, at the national scale as estimated by The shift Project. Report can be downloaded at https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf

[Click here to view linked References](#)

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5 **Insights on the carbon footprint of radiotherapy**
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54 **Titre court : Insights on the carbon footprint of radiotherapy**
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58 **Conflicts of interest**
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4 M.P.: Has shares and scientific advisor for Everzom, Evora bioscience, Therafast-Bio, D.A.:
5 conceptor of DCD, other authors: NA.
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10 **Contribution of the authors**

11
12 M.P. conceived the study, elaborated the methodology, wrote and validated the work.
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18 M.E., M.K. reviewed the manuscript
19

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21 A.A., C.M., S.R. and J.V. participated to the writing
22

23
24 D.A. analyzed the data and participated to the writing
25

26
27 G.D., S.S. coordinated the writing of the manuscript
28

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41
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48 **Mots clés**

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50 Radiothérapie, empreinte carbone, fractionnement, impact environnemental, stratégies de
51 diminution
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53 **Keywords**

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4 **Résumé**

5 Le système de santé français est responsable de 8% de l’empreinte carbone nationale. La
6 réalisation d'un scénario neutre en émission nécessiterait de diviser par 4 ou 5 les émissions
7 carbonées actuelles dans les années à venir. Cependant l’empreinte carbone de la radiothérapie
8 n'a pas été spécifiquement étudiée à ce jour.
9

10 Dans cette revue, nous résumons le contenu de la session du congrès de la SFRO dédiée à la
11 sobriété énergétique et à l'empreinte carbone de la radiothérapie. Nous discutons de l'empreinte
12 carbone du système de santé français et de nos travaux sur l'estimation de l'empreinte carbone
13 de la radiothérapie externe. Nous avons développé une méthodologie dédiée pour estimer
14 l'empreinte carbone liée aux traitements de radiothérapie et ainsi estimé les principales sources
15 d'émissions, à savoir les trajets des patients et des personnels, la fabrication et la maintenance
16 des accélérateurs et le stockage des données. Sur la base de l'empreinte carbone calculée dans
17 nos centres, nous proposons des stratégies de réduction et une estimation de leur potentiel
18 respectif. Nos résultats peuvent être extrapolés à d'autres paramètres internationaux en adaptant
19 les facteurs d'émission (kgCO₂/article ou euro) à d'autres paramètres nationaux.
20

21 La radiothérapie externe a une empreinte carbone majeure qui peut être diminuée de plusieurs
22 manières, notamment en modifiant le fractionnement des traitements. Ces modifications auraient
23 un impact important sur la manière dont les traitements de radiothérapie sont dispensés, ainsi
24 que sur l'organisation des soins en radiothérapie. Il faut donc en tenir compte dans la réflexion
25 sur l'avenir de la radiothérapie.
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33 Achieving a net zero emissions scenario will require a 4-5 fold decrease of carbon emissions in
34 the coming years. The carbon footprint of radiation therapy has not been specifically studied to
35 date.
36

37 In this review we summarize the content of the carbon footprint dedicated session in the SFRO
38 congress. We discuss the French healthcare system carbon footprint and its major drivers and
39 our work on the estimation of the carbon footprint of external beam radiation therapy in the French
40 setting. We developed a dedicated methodology to estimate the carbon footprint related to
41 radiation therapy treatments, and describe the main drivers of emissions based on a single center
42 as an example, namely patient's rides, accelerators acquisition and maintenance and data
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44 and an estimation of their respective potential. Our results may be extrapolated to other occidental
45 settings by adapting emission factors (kgCO₂/item or euro) to other national settings.
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50 EBRT has a major carbon footprint that may be mitigated in many ways that may impact how
51 radiation therapy treatments are delivered, as well as the national organization of the radiotherapy
52 sector. This needs to be taken into account when thinking about the future of radiotherapy.
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57 **Abstract**
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4 The French healthcare system is responsible for 8% of the national footprint. Achieving a net zero
5 emissions scenario will require a 4-5 fold decrease of carbon emissions in the coming years. The
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26 **Introduction**

27 Limiting warming to 2°C requires global greenhouse gas (GHG) emissions to be around 20
28 GtCO₂e/year around 2050¹ (or “net zero”). With an estimated world population of about 10 billion
29 people² this would represent 2 tCO₂e/year/person. Current French carbon footprint is around 9
30 tCO₂e/year/person³ meaning that French emission per capita should be reduced by a factor 4 to
31 5 during the next 30 years. Since there is no debate in the scientific community to state that
32 climate change can be attributed to human activities, all sectors of the society are concerned and
33 must initiate major changes in their organizations, including healthcare.
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38 In a 2021 study, updated in 2023, the think tank The Shift Project estimated the carbon footprint
39 of the French healthcare system to be 49 MtCO₂e/year, accounting for approximately 8% of the
40 nation's greenhouse gas emissions⁸. The study also highlighted that these emissions are
41 predominantly driven by the procurement of medications and medical devices, which collectively
42 contribute to slightly less than half of the sector's emissions. The study encompassed various
43 components of the healthcare system, including primary care, hospitals, services for the elderly
44 and disabled, public administration, and health insurance providers.
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48 The medical community has started to work on the relevancy of care pathways to achieve better
49 cost efficacy, but not yet for carbon efficacy. In order to do so, we need to better understand the
50 carbon footprint of health products, medicine and medical devices.
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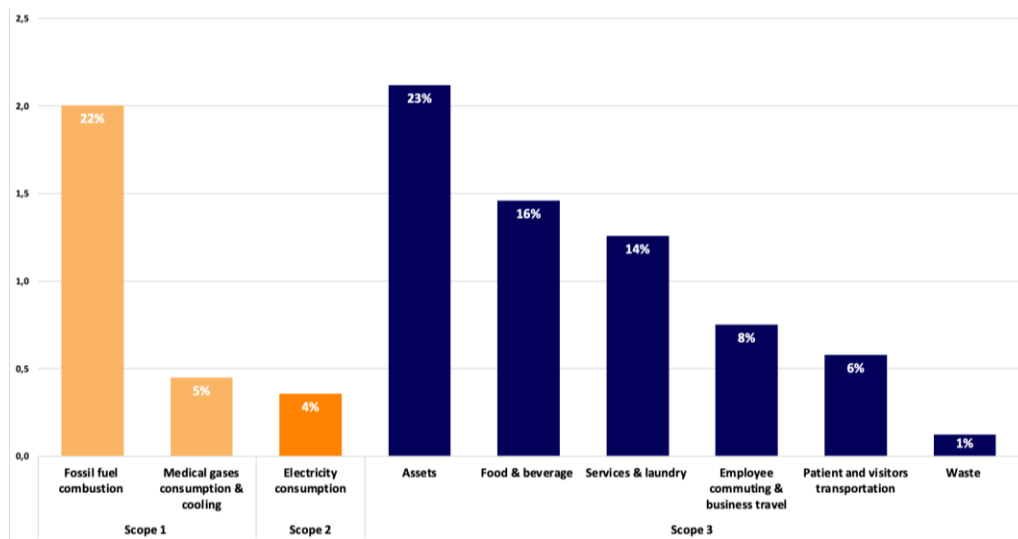
53 The carbon footprint of radiation therapy has not been specifically and deeply studied to date.
54 Only a few articles were published on this topic with a focus on electrical consumption or
55 transport⁵⁻⁷.
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58 The number of radiotherapy centers is limited to about 180 in France, implying sometimes long
59 distance travels for patients and staff. In addition, external beam radiation therapy (EBRT) relies
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4 on the use of a heavy technical platform, with linear accelerators installed in thick concrete vaults
5 and a huge amount of imaging data to store for decades. Thus, extrapolation of available data
6 from other healthcare settings to the EBRT context seems difficult. However, reducing GHG
7 emissions to achieve net zero emissions in 2050 requires a better understanding of the carbon
8 emissions main drivers. A dedicated carbon footprint methodology has been developed in order
9 to estimate the CO₂ emissions impact of a radiotherapy center. It takes into account energy
10 consumption, products and services use and patient trips (among other) to estimate carbon
11 emissions of the center. We determine the most impactful domains in terms of carbon emissions
12 in radiotherapy centers. Finally, we discuss ways to reduce the carbon footprint of EBRT.
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20 **The carbon footprint of hospitals in France**

21 For hospitals specifically, emissions excluding medications and medical devices were estimated
22 at 9.1 MtCO₂e/year. Of this total, 23% were attributed to assets, including building construction,
23 IT systems, furniture, machinery, and vehicles (Figure 1). Furthermore, 22% of emissions resulted
24 from the consumption of fossil fuels for purposes such as heating, air conditioning, and hot water.
25 Additionally, 16% of emissions were attributed to catering services, and 14% were associated
26 with the travel of healthcare professionals, as well as patients and visitors. Each year, the distance
27 covered by patients traveling to hospitals in France was estimated to be 5.5 billion kilometers,
28 which is equivalent to more than 7,000 round trips between Earth and the Moon. Although for
29 methodological reasons and data availability, the carbon footprint associated with hospital
30 purchases of healthcare products has not been estimated, it is likely to account for a significant
31 proportion of total emissions.
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55 **Figure 1 : Detailed carbon footprint of French hospitals, excluding medication and medical devices, at the national scale as**
56 **estimated by The shift Project. Report can be downloaded at [https://theshiftproject.org/wp-](https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf)**
57 **[content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf](https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf)**
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4 **Methodological aspect on the evaluation of carbon footprint of French radiotherapy**
5 **center**

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7 A full methodologic guide will be published elsewhere. Briefly, a specific methodology for
8 estimating the carbon footprint of French radiation therapy centers has been developed on the
9 basis of ISO 14064-2018 (ISO norm for carbon accounting), the GHG protocol (an international
10 multi-stakeholder partnership for carbon accounting) and the Bilan Carbone® methodology
11 version 8 (a French NGO for carbon accounting). At the French level, we mostly relied on the
12 Base Empreinte® database and the ADEME (Agence De l'Environnement et de Maîtrise de
13 l'Energie) sectoral guide for French Healthcare sector and the report from the Shift Project (a
14 French NGO) on the french health sector.
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18 *Organizational perimeter*

19 We concentrated our evaluation on EBRT, excluding brachytherapy and hospitalization. We
20 included the full scope 1 (direct CO2 emissions like fuel consumption), scope 2 (indirect
21 consumption like electricity), and almost all of the upstream scope 3 (medical devices, drugs,
22 machines, etc) and some of the downstream scope 3 (waste, etc). Specifically, only the carbon
23 footprint of prescribed care (drugs, radiology, biology) related to radiotherapy has been taken into
24 account and potential others excluded.
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28 *Functional unit*

29 In order to ensure comparability, the total carbon footprint of an entity must be divided by a
30 production unit. We propose to use one EBRT treatment as this denominator and to calculate the
31 carbon footprint of one EBRT treatment. Alternatively, the carbon footprint related to the delivery
32 of one fraction was used as a secondary functional unit.
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36 *Reports*

37 On top of the classical sources in national and international guidelines, we propose to specifically
38 report the following sources. Correspondence with international classification are in brackets.
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- 41 - Fuel (Direct energy consumption - mobile sources with thermal motor - part 2)
- 42 - Gas (Direct energy consumption - fixed source of combustion - part 1)
- 43 - Electricity (part 6)
- 44 - Collective heating (part 7)
- 45 - SF6 (fugitive emissions - part 4)
- 46 - Desk material (part 10),
- 47 - Medical material (part 10)
- 48 - Heating, Ventilation, and Air Conditioning (HVAC) system construction (part 10),
- 49 - Buildings & bunkers (part 10)
- 50 - Accelerators & CT scanners (part 10)
- 51 - IT material (part 10)
- 52 - Patients transportation (part 16)
- 53 - Workers transportation (part 13 and 22)
- 54 - Servers (part 9 if externalized, 10 otherwise)
- 55 - Waste (part 11)
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- 4 - Medical consumables (part 9)
- 5 - Desk consumables (part 9)
- 6 - Other capital goods (part 10)
- 7 - Other purchased services, including laundry and software licenses (part 9)
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10 We searched the literature for specific emission factors (in kgCO₂e/euro) or value per item (in
11 kgCO₂/unit) to account for each of these subparts. We established a methodology to estimate
12 the carbon footprint of radiotherapy centers. For accelerators, CT scanners and their
13 maintenance, we used an emission factor (kgCO₂/euro) proposed by manufacturers, in good
14 agreement with emission factors proposed by ADEME, taking amortization into account. Large,
15 small material and information technology was accounted for using adapted emission factors or
16 the estimated best carbon footprint when available taking into account amortization. Distance and
17 mode of transport of patients and workers were collected and transformed in carbon footprint
18 using emission factors per kilometer for each transport method. Medical device and drugs carbon
19 footprint was estimated using the total expenses spent in the RT facility as well as the one
20 associated with the patient care pathway multiplied by the adapted reported emission factor of
21 the medical device or drug industry (ADEME).
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27 **Evaluation of carbon footprint of a French radiotherapy center**

28 As an example, we report the relative carbon footprint of the Versailles radiotherapy center in
29 2022 using this methodology. Patients' trips were the most emissive subpart (about 30%),
30 followed by accelerators & scanners construction, maintenance and disposal. The less CO₂
31 intensive subparts in order of importance were servers, medical material, HVAC, buildings and
32 bunkers and workers transportation. Direct and indirect energy consumption was limited to
33 electricity which accounted for 2 - 3% of the total carbon footprint. Detailed results will be
34 presented during the SFRO congress.
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38 Of note, our multicentric study limits are that (i) it is limited to the French setting at the moment
39 and will discuss how our estimation may be extrapolated to other countries and what are the key
40 factors to take into account, (ii) is limited to EBRT and (iii) that a substantial uncertainty surrounds
41 the value of carbon emission estimated per treatment strategy.
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45 **Mitigations strategies**

46 Mitigation strategies should preferentially target the most emissive subparts of the footprint.
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49 *a) Evaluation of the impact\benefit ratio of new machines*

50 Complex accelerators result in larger GHG emissions. The clinical benefit of these costly
51 machines should be thoroughly evaluated and carefully weighted against their environmental
52 impact before being used in clinical routine.
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56 *b) Hypofractionation*

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4 A classical treatment comprises an initial consultation, a planning CT scanner and a set-up,
5 followed by 1 to 40 fractions. Patients' ride emissions are almost linearly linked to the number of
6 fractions. Moreover, hypofractionation also reduces the number of accelerators needed to perform
7 a given amount of treatments, lowering accelerators, bunkers and workers needed among others.
8 Therefore, hypofractionation is a very effective mitigation strategy.
9

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11 *c) Geographical appropriateness*

12 Patients are not always treated in the closest radiotherapy center available, including for palliative
13 treatments. Geographical appropriateness when clinically possible, *i.e.* treating the patients in the
14 closest center from where they live, could lead to significant reduction in patient transportation
15 distance.
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19 *d) Transport mode appropriateness*

20 Use of public transportation when clinically possible could lead to significant reduction in patients'
21 transportation emissions. Similarly, use of normal vehicles versus ambulances limits carbon
22 emissions, as well as use of personal vehicles that limit the number of kilometers traveled. The
23 organization of shared travels could make it possible to reduce this impact.
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27 *e) Data deletion policy*

28 Data storage in servers is the third most emissive subpart. Moreover, data storage per treatment
29 is rising over time as resolution increases. From a purely mathematical point of view, with no
30 change in data deletion policy, the amount of stored data will continue to rise exponentially. An
31 updated data deletion policy is needed to achieve stabilization in data storage volume in the
32 coming years.
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36 *f) Communication with patients and workers*

37 Most of the previously described mitigations strategies will require both patient and workers
38 collaboration. Awareness about the climate change impact of radiotherapy treatments as well as
39 the most emissive parts of it needs to be better understood by these two populations in order to
40 obtain these collaborations.
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43 The potential reductions associated with the discussed mitigations strategies a) to f) have been
44 quantified using Versailles 2022 carbon and activity report and will be presented during the
45 congress.
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48
49 **Conclusion**

50
51 Radiotherapy has a role to play in carbon emission mitigation. EBRT has a major carbon footprint
52 that may be mitigated in many ways like hypofractionation, careful evaluation of the impact of new
53 accelerators before their large dissemination and new data deletion policies among others. The
54 accelerator industry also should engage deeper into this decarbonation approach of the sector.
55 All these mitigation strategies may impact how radiation therapy treatments are delivered, as well
56 as the national organization of the radiotherapy sector. This needs to be taken into account when
57 thinking about the future of radiotherapy.
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