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Health and Environmental Issues of Red Meat

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Summary

- *Meat plays an important role in traditional French cuisine, but it is becoming an increasingly controversial topic.*
- *Red meats all have a relatively high iron content, which is particularly well absorbed by the body in the form of haem iron. But eating too much red meat has been proven to cause cancer. This has led health authorities to encourage eating red meats in moderation, while research is being conducted to limit the negative effects associated with producing, preparing and eating red meat.*
- *Cattle farming has a significant impact on the environment, and this fact has led to new developments in terms of livestock feed and new agricultural-ecological practices.*

Antoine Herth, MP, Member of the Office

"Red meat", a cultural concept

There is no strict definition of red meat. It does not correspond to a chemical definition, nor to a single production method. The reference to a certain colour does not necessarily correspond to what is immediately observed. As cultural historians have shown, the **actual colour is not necessarily that which is described and perceived**.[1] But this trend has led, among other things, to veal calves being deprived of solid iron-rich foods, such as grass, in order to meet French expectations in terms of colour.[2] For the purpose of this briefing, the term "red meat" means "non-poultry meat", including pork.[3]

Red meat is traditionally regarded as a **highly beneficial, nutrient-rich** and even essential part of our diet.[4] As the Organisation for Economic Co-operation and Development (OECD) points out, its consumption is linked to standard of living and higher incomes.[5] However, in the more economically advanced countries, this relationship is gradually shifting in the opposite direction within the population.[6]

In France, 32% of the population consumes at least 500 grams of red meat per week, this proportion being higher among men (41%) than among women (24.1%).[7] This has an impact on both human health and the environment, due to its carbon footprint. **Can we have high quality, nutritious food with a low carbon impact? What are the solutions for improving red meat's carbon footprint, its human health benefits, or both?** Can these solutions be developed through partnerships between scientific research institutions and livestock farms? Are they already?

Red meat and human health - benefits and dangers

- **Chemical properties**

Red meat contains a high level of haem iron. This type of iron is found in haemoglobin and myoglobin. However, the European Food Safety Authority (EFSA) concluded from a review of published studies on the subject that "the haem iron content of meat varies considerably" from one meat to another.[8] EFSA has established that the percentage of haem iron is 69% of the total iron content in beef and 39% in pork. So, "after black pudding, beef has the highest total iron and haem iron content, and is significantly higher than mutton, pork and poultry."[9]

Cooking can reduce the amount of haem iron. For example, more is lost when lamb is boiled than when it is roasted.[10] Therefore, the **way in which the food is prepared** needs to be taken into account when measuring its effect on human health.

- **Haem iron - better absorption**

Since iron deficiency can lead to anaemia, red meat has a comparative advantage over other foods in dietary terms, as haem iron is more easily absorbed by the body. Haem iron, which is found in meat and fish, is better absorbed by the body than non-haem iron, which is found in vegetables and dairy products.[11] "70% of the iron consumed in the French diet is non-haem iron, but it represents only 20% of the iron found in the body; on the other hand, haem iron represents only 30% of the iron ingested, but 80% of the iron in the body is derived from it."[12] Other factors come into play, however, such as diet or the characteristics of the individual concerned.[13]

In France, according to available epidemiological studies, the risks of advanced forms of iron deficiency corresponding to iron deficiency anaemia are quite low

among the general population, however, since they affect only 3% to 4% of women of child-bearing age.[14]

- **Cancer risk**

While eating red meat has its benefits, it also has its risks. "Experimental studies have identified haem iron as a major factor in meat-induced colonic carcinogenesis".[15] During digestion, haem iron produces an enzymatic reaction that catalyses the oxidation of lipids to form alkenals. These alkenals are both cytotoxic and genotoxic, i.e. they lyse colonic cells and cause breaks in their DNA.

The National Nutrition and Health Programme (PNNS – Programme national nutrition santé) therefore recommends that people should not eat more than 500 grams of red meat per week.[16] For deli meats, or *charcuterie*, the maximum limit is set at 150 grams per week (PNNS 2019-2023). In 2018, the International Agency for Research on Cancer classified deli meats as a known human carcinogen. This was based on the findings of a working group of 22 international experts.[17]

In 2015, more than 4,000 cancers were attributable to the consumption of processed meat in France. More than 4/5 of these were colorectal cancers. During the same period, there were approximately 2,000 cancers attributable to red meat consumption, with roughly the same proportion of colorectal cancers. The WHO has also classified red meat as carcinogenic. Based on meta-analyses, it estimates that eating 100g of red meat per day increases the risk of death from this type of cancer by an average of 17%. This increase is 18% if 50 g of deli meats are consumed each day.

- **Cardiovascular risks**

Two meta-analyses have shown that eating more meat and processed meat is associated with a significant increase in the risk of cardiovascular disease, particularly stroke: eating 50g of processed meat increases the risk of stroke by 42%[18] and eating 100g of meat, half of which is processed, increases the same risk by 10%.[19]

For both colorectal cancer and cardiovascular disease, reducing red meat consumption has been shown to reduce the associated risks. This health recommendation is particularly relevant for people who eat a lot of red meat (eight times per week).[20]

- **Can we expect to see new recommendations?**

Initial experimental studies suggest that this effect may be reduced by consuming certain antioxidants, such as polyphenols.[21] For example, an epidemiological study found a reduced risk of colorectal adenomas in women who eat a lot of antioxidants. Including vegetables in the same food bowl may reduce the carcinogenic risk associated with meat consumption.

The results do not provide a sufficient level of evidence to establish a prevention policy for the general population, or at least not yet, but current research is promising.

- **Objective risk reduction strategies**

The consensus of the consulted practitioners is that nutrition recommendations only affect those who are already aware of them and therefore less concerned by them. In this respect, the trials carried out to improve the supply of meat itself, in terms of its benefits for human health, are particularly significant.[22]

Some meat preparation methods prevent lipid peroxidation during ingestion. Marinating beef with extracts of grape-olive antioxidants is one of these prevention methods.[23] Turmeric is also a good choice of seasoning, but it makes the meat less attractive to consumers as it affects its "red" colour.[24]

Further up the food chain, at the production stage, "recognising the role of peroxidation and nitrosylation opens up the possibility of reducing nutritional risks by adding antioxidants (...) to meat products during production or by incorporating them into livestock feed".[25] The use of antioxidants in cattle feed may even have a twofold benefit, for human health and for the environment, as it reduces the methanogenic activity of cattle.

Red meat and the environment

Red meat consumption has environmental implications, particularly for animal welfare, direct pollution and carbon footprint. The first two points depend largely on the farming method and are beyond the scope of this briefing, even though they are the subject of serious debate in society.

The focus here will be on ruminant livestock, mainly cattle, and the significant contribution it makes to greenhouse gas (GHG) emissions. We can therefore assume that cutting meat out of our diet is better for the climate. A recent study has established a Kaya equation in which the number of livestock appears to be the main multiplier of GHG emissions from livestock farming in France. But the authors themselves believe that "the potential to reduce GHG emissions is difficult to understand unless we adopt a systemic approach that takes into account other external environmental factors such as biodiversity, soil conservation, carbon stocks and animal welfare".[26]

In fact, some agricultural areas cannot be used for anything other than livestock farming, unless they are converted to other uses such as forestry.

A more detailed approach shows a marked variation in emissions according to the type of farming. For every 100g of protein produced in the form of beef, the average carbon footprint is 25 kilograms in carbon dioxide equivalents, but the values show a wide statistical spread,[27] from 9kg for the first decile to 105kg for the last. This has prompted a great deal of research into how to make production techniques more carbon

efficient.

- **Measuring environmental impact**

The environmental balance of beef and veal varies according to the calculation methods used.

The FAO uses the "*life cycle assessment*" to attribute 14.5% of anthropogenic emissions to livestock farming. This includes emissions from the entire supply chain, from land use and producing feed, through to breeding, slaughter and transporting the meat to the point of sale "With emissions estimated at 7.1 giga-tonnes of carbon dioxide equivalents per year, or 14.5% of human-induced GHG emissions, it is clear that the livestock sector plays a significant role in climate change, with beef and dairy production accounting for the majority of these emissions, at 41% and 20% respectively." [28] However, significant differences in estimates have been reported.[29]

In any case, direct emissions from individual farms are not solely attributable to animals. Of course, the main gases emitted are methane (CH_4) generated by enteric fermentation and livestock manure, and nitrous oxide (N_2O), essentially linked to the agro-system nitrogen cycle (nitrogen emissions from fertilisers and manure, and ammonia emissions from livestock farming - mainly cattle). Carbon dioxide (CO_2) is produced by burning fossil fuels (mainly tractor fuel) and soil treatments such as lime.[30]

Nevertheless, the main source of methane (CH_4) emissions in mainland France is livestock farming. This is due to enteric fermentation and the handling of animal waste, with the remainder corresponding to emissions from rice fields. Between 1990 and 2017, these emissions decreased slightly, mainly owing to a decrease in the number of dairy cows. But other factors have had the opposite effect, such as the increase in manure management systems. In terms of CO_2 equivalent, the livestock sub-sector represents 48% of emissions from the agricultural sector, mainly due to CH_4.[31]

- **Positive external environmental factors**

While the livestock sector's negative environmental impact often far exceeds the impact of the livestock itself, agricultural experts are calling for its positive environmental factors to be taken into account as well.[32]

Grass-fed livestock contributes to producing high-quality water thanks to the filtering power of the grasslands.[33]

Secondly, ruminants can produce milk and meat from fodder that is not suitable for human consumption. Furthermore, grassland stores carbon. [34] Finally, sustainable grasslands are recognised as an important source of biodiversity in Europe.

- **A broader environmental impact**

To measure the environmental impact of livestock farming, there are five main factors to be considered: GHG emissions and changes in soil carbon stocks, water quality, air quality, the use of natural resources, and land use and the impact on biodiversity.[35]

- **Available action mechanisms**

In a report, INRAE proposed ten measures to reduce the environmental impact of livestock farming,[36] including: reduce the use of synthetic mineral fertilisers, by making better use of them and by increasing the value of organic resources, in order to reduce N_2O emissions; increase the share of legumes in field crops and temporary grasslands; develop No-Till Agriculture Practices to store carbon in the soil; reduce the amount of protein in animal feed to limit the nitrogen content of manure and reduce N_2O emissions; encourage agro-forestry and the planting of hedgerows to increase carbon storage in the soil and plant biomass; optimise grassland management to improve carbon storage; develop technologies, particularly methanisation, and install gas flares to reduce CH_4 emissions associated with the storage of manure.

- **Indirect improvements**

Several indirect avenues for improvement are being explored. First of all, fatty waste from the food industry can be recycled or reused, thus reducing mass losses.[37] In addition, there are a number of strategies for reducing air pollutants and GHG emissions generated by agriculture and farming.[38] Ammonia (NH_3) mitigation measures can be applied to livestock buildings (air cleaning and removing animal waste), as well as to manure storage (covering storage pits and manure piles) and manure spreading (faster incorporation into the soil).

Finally, methanisation, as a natural biological process, enables us to use organic matter, such as waste, livestock manure or crop surplus, to produce biogas. This biogas can be used to generate electricity and heat co-generation), or injected into the natural gas network (purified biogas). Using biogas as a renewable source of heat, electricity or fuel can replace the use of CO_2-emitting fossil fuels. [39]

- **The specifics of enteric fermentation**

Ruminants get their name from the enteric fermentation that takes place in their rumen. This fermentation leads to the formation of methane (CH_4), the extent of which depends on the species, their development, and the quality and quantity of the food they eat.

In its 7th recommendation, INRAE proposes substituting carbohydrates for unsaturated fats in intensive livestock farming and using an additive (nitrate) in cattle feed in order to reduce enteric CH_4 production. According to some studies, adding legumes and chicory to cattle feed could reduce enteric methane emissions by up to 20%.[40]

- **Direct improvements**

Another area where significant improvements can be made is in livestock farming practices.

For example, one study has shown how the genetic qualities of Charolais cattle can be combined with a more efficient animal feed to reduce enteric methane emissions.[41] Therefore, genetically improving livestock breeds is one way to mitigate the problem.

More specifically, in France, heifers calve at 28 or 29 months, compared with 24 months elsewhere in Europe. By calving them earlier, we could reduce the average GHG emissions of a farm by about 3%.[42] A better balance between dairy and beef cows, or suckler cows, which produce less meat for the same amount of grass (or feed) consumed, also helps to control environmental impact.[43]

However, neither the objective evaluation of the environmental impact of local livestock farms nor the search for practical improvements are sufficient to address the issue of the need for traceability of imported products, particularly with regard to deforestation and biodiversity losses.[44]

- **Cattle: a link in the biodiversity chain?**

An INRAE study has highlighted that "dejecta [from domestic herbivores, sheep, cattle, horses] contribute to biodiversity in agricultural systems through their impact on environmental heterogeneity".[45] Their presence in the grassland ecosystem helps to maintain coprophagous beetles, commonly known as dung beetles.[46]

Taking this approach to the extreme, the Dutch Taurus Foundation supports experiments in rewilding. This is based on re-introducing large herbivores, in the Côa Valley (Portugal) with wild horses,[47] or in the southern Carpathians in the form of bison.[48] In these radical experiments, humans take a back seat to nature, and the entire biodiversity chain is reconstituted without us.

Nutritional choices and the environment

The models developed for analysing the environmental impact of red meat are based on complex nutritional assumptions. People can choose from a range of balanced diets in which meat is more or less important, or sometimes not included at all.[49] These diets are not built up by simple substitution – for example, replacing animal proteins with plant proteins – but require comprehensive regulation.

Recommendations for healthy and sustainable diets are very much dependent on culture, tradition and society. This briefing demonstrates that the health and environmental impact of red meat can be improved, particularly through moderating its consumption, without necessarily eliminating it.

The Office's websites:

http://www.assemblee-nationale.fr/commissions/opecst-index.asp

http://www.senat.fr/opecst

Persons consulted

Mrs. Carine Barbier, CNRS Research Engineer and co-author of a study on the carbon content of household food in France

Mrs. Marie-Christine Boutron-Ruault, Inserm DR1 Research Director and internal gastroenterological specialist

Mr. Jean-Louis Peyraud, Associate Scientific Director for Agriculture at the INRAE

Mr. Fabrice Pierre, Deputy Head of the INRAE "Human Nutrition" Department and Head of the "Prevention and Promotion of Carcinogenesis by Food" team at the INRAE ToxAlim research unit

Mr Franck Porcher, Managing Director, Cécile Crespel, Sales Manager, Justine Bercy, Engineer, Charlotte Epinay, Communications Consultant, and Théo Mannechez, Research Officer, from Cooperl Environnement

References

[1] *Michel Pastoureau (2010). "Les Couleurs de nos souvenirs" (The Colours of our Memories). Published by Éditions du Seuil, "The 21st Century Bookshop", 2010*

[2] *Under the heading "Welfare and Protection of Calves" (sic), the Ministry for Agriculture presents the situation as follows: "Veal calves are cattle that are slaughtered by the time they are 8 months old. They are bred for their meat. The meat should be a light pink colour in order to satisfy the expectations of French consumers. At birth, the calves' muscles are light in colour. They turn red when the animals start eating iron-rich foods, such as grass. The calves are kept in a barn or cowshed to prevent them from eating it." https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-veaux A briefing from the Assemblée nationale on nitrite salts in the food industry, published in January 2021, gives an example of the same phenomenon in deli meats (charcuterie), stating that "the natural colour of cooked meat, namely ham, is not pink, but rather brown, grey or beige", and that this colour is modified by adding nitrite salts. https://www.assemblee-nationale.fr/dyn/15/rapports/cion-eco/l15b3731_rapport-information#*

[3] *Public notice issued by the French National Food Safety Agency (ANSES) in December 2016, Collective expertise report, "Updating the National Nutrition and Health Programme (PNNS) guidelines: revision of the food consumption guidelines", page 27: "In most epidemiological studies and in international expert literature, the term "non-poultry meat", i.e. beef, pork, veal, mutton, lamb, goat and horse meat, is grouped under the term "red meat". To avoid any risk of confusion with the term "red meat", which in French includes beef, mutton, lamb and horsemeat, the term "non- poultry meat" is used in this document." For the record, many other species are also eaten around the world: rabbits, kangaroos, deer, wild boar, etc.... https://www.anses.fr/fr/system/files/NUT2012SA0103Ra-1.pdf*

[4] *Roland Barthes (1951). "Le bifteck et les frites" (Steak and chips), Mythologies, published by Éditions du Seuil, coll. "Points", pages 72-74*

[5] *The OECD (2021), Meat consumption (indicator). https://data.oecd.org/fr/agroutput/consommation-de-viande.htm*

[6] *G. Tavoularis G. and E. Sauvage, 2018, The new generations are transforming meat consumption, Consumption and lifestyles, CREDOC No. 300, Deloitte Sustainable Development, September 2018 https://www.credoc.fr/download/pdf/4p/CMV300.pdf*

[7] *Santé publique France (2019), "Adéquation aux nouvelles recommandations alimentaires des adultes âgés de 18 à 54 ans vivant en France" (Compliance with the new dietary recommendations for adults aged 18 to 54 living in France), https://www.santepubliquefrance.fr/determinants-de-sante/nutrition-et-activite-physique/documents/rapport-synthese/adequation-aux-nouvelles-recommandations-alimentaires-des-adultes-ages-de-18-a-54-ans-vivant-en-france-etude-esteban-2014-2016.-volet-nutrition (table 2, page 3)*

[8] *European Food Safety Authority (EFSA), Scientific Opinion of 23 September 2015 on dietary reference values for iron, EFSA Journal, 21 October 2015, page 13: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2015.4254. The EFSA refers to HF Balder, J Vogel, MC Jansen, MP Weijenberg, PA van den Brand, S Westenbrink, R van der Meer and RA Goldbohm, 2006. Heme and chlorophyll intake and risk of colorectal cancer in the Netherlands cohort study. Cancer Epidemiology, Biomarkers and Prevention, 15, 717-725 https://cebp.aacrjournals.org/content/cebp/15/4/717.full.pdf*

[9] *The National Academy of Medicine Bulletin (November 2011), Volume 195, No. 8, Report from the joint session of the French Academy of Agriculture and the National Academy of Medicine concerning beef in the diet, pages 1783-1829: "After black pudding, beef has the highest total iron and Heme iron content, and is significantly higher than mutton, pork and poultry" (page 1791) https://www.academie-medecine.fr/apports-nutritifs-des-viandes-bovines/*

[10] *A Pourkhalili, M Mirlohi and E Rahimi (2013). Heme iron content in lamb meat is differentially altered upon boiling, grilling, or frying as assessed by four distinct analytical methods. Scientific World Journal, 2013, 374030*

https://www.researchgate.net/publication/237057692_Heme_Iron_Content_in_Lamb_Meat_Is_Differentially_Altered_upon_Boiling_Grilling_or_Frying_as_Assessed_by_Four_Distinct_Analytical_Methods

[11] *Valérie Weinborn, Fernando Pizarro, Manuel Olivares, Alex Brito, Miguel Arredondo, Sebastián Flores and Carolina Valenzuela, "The Effect of Plant Proteins Derived from Cereals and Legumes on Heme Iron Absorption", Nutrients, vol. 7, No. 11, November 2015, p. 8,977–8,986.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4663574/ *"Hallberg and Rossander found that when half of the meat was replaced by "soy-meat" in hamburgers, the total amount of Fe absorbed, including Heme Fe, was much lower. The addition of Heme Fe as blood to the half meat, half soy hamburgers resulted in an increase in the absorption of Fe to the level measured in all meat hamburgers."*

[12] *See the National Academy of Medicine Bulletin (November 2011), vol. 195, No. 8, supra.*

[13] *European Food Safety Authority (EFSA), Scientific Opinion of 23 September 2015 on dietary reference values for iron: "Iron is inefficiently and variably absorbed, depending on dietary and host-related factors." (p. 2)*

[14] *We thank Professor Serge Hercberg, President of the National Nutrition and Health Program, for drawing our attention to this point. The rates observed in non-menopausal women are in line with the PNNS2 public health objective (3%), but with some social inequalities. In fact, only women of child-bearing age in very precarious situations or in the Overseas Departments and pregnant women seem to be at high risk of iron deficiency anaemia.*

[15] *Marie-Christine Boutron-Ruault, Fabrice Pierre and Nadia Bastide (2018). Haem iron consumption and risk of colorectal carcinogenesis: interaction study with potentially protective polyphenols in the E3N cohort, and experimental validation in vivo.* https://www.anses.fr/fr/system/files/181002-PNREST-PlanCancer-DP.pdf

[16] *Programme national nutrition santé (National Nutrition and Health Programme) 2019-2023* https://solidarites-sante.gouv.fr/IMG/pdf/pnns4_2019-2023.pdf *Among the specific objectives defined by the High Council for Public Health in its recommendation issued on 9 February 2018, one of them concerns non-poultry meat: "The consumption of "red" meat (i.e. beef, pork, veal, mutton, goat, horse, wild boar and deer) should be reduced in the population to the point where 100% of the population consumes less than 500g of meat per week"*

[17] *See the Assemblée nationale's report on nitrite salts in the food industry:* https://www.assemblee-nationale.fr/dyn/15/rapports/cion-eco/l15b3731_rapport-information.pdf *(p. 43)*

[18] *R. Micha, S.K. Wallace and D. Mozaffarian (2010). Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. Circulation 121, 2271-83.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2885952/ *The IARC defines processed meat as meat that has been "processed by salting, curing, fermenting, smoking, or other processes to enhance its flavour or improve its preservation. The majority of processed meats contain pork or beef, but processed meats may also contain other red meats, poultry meat, offal, and other by-products such as blood" (IARC monographs on the evaluation of carcinogenic risks to humans; volume 114, page 37)* https://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Red-Meat-And-Processed-Meat-2018

[19] *G-C Chen, D-B Lv, Z Pang & Q-F Liu (2013). Red and processed meat consumption and risk of stroke: a meta-analysis of prospective cohort studies. European Journal of Clinical Nutrition 67, 91-95.* https://www.nature.com/articles/ejcn2012180

[20] *This information was provided to the rapporteur by Mr. Fabrice Pierre (see the list of persons consulted). In the study cited in point 23, the different consumption rates are defined as follows: "Averaged across studies, consumption (mean±SD) levels in the lowest vs. highest category of intake were 1.1±1.1 vs. 8.3±2.7 servings/week for red, 0.4±0.8 vs. 5.7±3.9 servings/week for processed, and 1.8±1.7 vs. 10.5±4.2 servings/week for total meat intake, respectively."*

[21] *See reference cited in the previous briefing, page 23.*

[22] *Nadia Bastide, November 2012, Heme iron and colorectal carcinogenesis, Study of mechanisms and research into preventive strategies, doctoral thesis from the University of Toulouse III, page 4: "(...) adding protective molecules to the production process of deli meats could help prevent colorectal cancer throughout the entire population, including the socially disadvantaged, who tend to be less receptive to dietary recommendations."*

[23] *Targeting colon luminal lipid peroxidation limits colon carcinogenesis associated with red meat consumption. Océane Martin, Nathalie Naud, Sylviane Taché, Laurent Debrauwer, Sylvie Chevolleau, Jacques Dupuy, Céline Chantelauze, Denis Durand, Estelle Pujos-Guillot Florence Blas-Y-Estrada, Christine Urbano, Gunter GC Kuhnle, Véronique Santé-Lhoutellier, Thierry Sayd, Didier Viala, Adeline Blot, Nathalie Meunier, Pascal Schlich, Didier Attaix, Françoise Guéraud, Valérie Scislowski, Denis E. Corpet and Fabrice HF Pierre. Cancer Prev Res - June 28 2018 - DOI:* 10.1158/1940-6207.CAPR-17-0361

[24] *This information was provided to the rapporteur by Mr. Fabrice Pierre (see the list of persons consulted).*

[25] *Mr. Fabrice Pierre. Positive association between the consumption of red meat, deli meats and the risk of colon cancer: could we prevent it by modifying production and breeding methods? Innovations Agronomiques (Agricultural Innovations), INRAE, 2019, 78, pages 117-125.* (10.15454/8rkb-a908). (hal-02915127)

[26] *Following the presentation to the Council of Ministers of the "Climate and Resilience" bill resulting from the Citizens' Climate Convention, the Ministry for Ecological Transition commissioned the Boston Consulting Group to carry out a study to assess the impact of measures taken since 2017, as well as those currently being considered, on the low-carbon trajectory in terms of reducing greenhouse gas emissions by 40% by 2030. For livestock, see page 14.* https://www.actu-environnement.com/media/pdf/news-37027-etude-bcg-loi-climat.pdf *The authors refer to "Climate change, water, agriculture: what trajectories for 2050?", a joint study by the General Council for the Environment and Sustainable Development (Conseil général de l'environnement et du développement durable - CGEDD) and the General Council for Food, Agriculture and Rural Areas (Conseil général de l'alimentation, de l''griculture et des espaces ruraux - CGAAER), published in December 2020* https://agriculture.gouv.fr/changement-climatique-eau-agriculture-quelles-trajectoires-dici-2050 *With regard to the carbon footprint, it refers to the INRA study published in June 2019 - "Storing carbon in French soils: how much potential do we have to reach the "4 in 1000" objective and what will it cost?"* https://www.territoires-climat.ademe.fr/actualite/etude-de-linra-stocker-du-carbone-dans-les-sols-francais-quel-potentiel-au-regard-de-lobjectif-4-pour-1000-et-a-quel-cout

[27] *Hannah Ritchie and Max Roser (2020) - "Environmental impacts of food production". Published online at OurWorldInData.org. Retrieved from:* https://ourworldindata.org/environmental-impacts-of-food

[28] *P. J. Gerber et al. (2013). "Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities" (FAO, 2013).* http://www.fao.org/3/a-i3437e.pdf *Quote from page 13*

[29] *Louis Schweitzer (2020). Should we stop eating meat? (particularly page 65 onwards, "A disputed calculation").*

[30] *C. Barbier, C. Couturier, P. Pourouchottamin, J-M. Cayla, M. Sylvestre and I. Pharabod (2019). "The energy and carbon footprint of food production in France ", Club Ingénierie Prospective Energie et Environnement (the Energy and Environment Prospective Engineering Club), Paris, IDDRI, 24 pages, January 2019.* http://www2.centre-cired.fr/IMG/pdf/empreinte_carbone_alimentation_en_france_fr_052019.pdf *(page 6)*

[31] *Greenhouse gases and air pollutants. Emissions assessment in France from 1990 to 2017. National Inventory Report. SECTEN report by the CITEPA, 2019.*

[32] *The National Academy of Medicine Bulletin (November 2011), Volume 195, No. 8, Report from the joint session of the French Academy of Agriculture and the National Academy of Medicine concerning beef in the diet, Contributed by Jean-Louis Peyraud,* https://www.academie-medecine.fr/dimension-economique-et-impact-environnemental-de-la-production-de-viande-bovine-en-france/

[33] *Insofar as the permanent vegetation cover contributes to limiting the risk of water eutrophication, i.e. the imbalance of aquatic environments caused by an increased concentration of nitrogen and phosphorus. However, these grasslands need organic fertilisation and, to a lesser extent, mineral fertilisation with nitrogen, phosphorus and potassium. INRA (March 2012), J.-L. Peyraud, P. Cellier, (co-ord.), F. Aarts, F. Béline, C. Bockstaller, M. Bourblanc, L. Delaby, C. Donnars, J.Y. Dourmad, P. Dupraz, P. Durand, P. Faverdin, J.L. Fiorelli, C. Gaigné, A. Girard, F. Guillaume, P. Kuikman, A. Langlais, P. Le Goffe, S. Le Perchec, P. Lescoat, T. Morvan, C. Nicourt, V. Parnaudeau, J.L. Peyraud, O. Réchauchère, P. Rochette, F. Vertes, and P.Veysset. Nitrogen emissions from livestock farming, reducing losses and restoring balance. Collective scientific expertise report, the INRA (France), 527 pages.* https://belinra.inrae.fr/doc_num.php?explnum_id=1794 *See in particular "Nitrogen emissions related to grasslands and cropping systems", page 257 onwards.*

[34] *A. Gac, J. Agabriel, J.-B. Dollé, P. Faverdin and H. Van Der Werf, "Greenhouse gas mitigation potential in cattle production", Innovations Agronomiques (Agricultural Innovations) 37 (2014), 67-81, notably page 71* http://idele.fr/fileadmin/medias/Documents/INNOVATIONS_AGRONOMIQUES_37_00-07-2014_67-81.pdf

[35] *M. Doreau, A. Farruggia, & P. VEYSSET (2017). Amenities and environmental impacts of French farms raising cattle for meat. INRAE Animal Productions, 30(2), 165-178.* https://doi.org/10.20870/productions-animales.2017.30.2.2242

[36] *S. Pellerin, L. Bamière, D. Angers, F. Béline, M. Benoît, J.P. Butault, C. Chenu, C. Colnenne-David, S. De Cara, N. Delame, M. Doreau, P. Dupraz, P. Faverdin, F. Garcia-Launay, M. Hassouna, C. Hénault, M.H. Jeuffroy, K. Klumpp, A. Metay, D. Moran, S. Recous, E. Samson, I. Savini and L. Pardon, 2013. How can French agriculture contribute to reducing greenhouse gas emissions? Mitigation potential and the costs associated with the ten technical actions. Study report, INRA (France), 454 pages* https://www.inrae.fr/sites/default/files/pdf/37cdee0e58f99f555be7f4655faf63c0.pdf *The 2 remaining recommendations are: Introduce more intermediate crops, inter-crops and grass strips in cropping systems in order to store carbon in the soil and reduce N_2O emissions; reduce fossil fuel use for agricultural buildings and equipment in order to reduce direct CO_2 emissions.*

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nitrogen oxides. *https://www.researchgate.net/publication/319976275_Mesurer_les_emissions_gazeuses_en_elevage_gaz_a_effet_de_serre_ammoniac_et_oxydes_d%27azote*

[39] *Paul Laurent, Sophie Benchimol and David Guianvarc (2016). Technical, economic and environmental study on the large-scale injection of bio methane into the natural gas network.* *https://www.ademe.fr/sites/default/files/assets/documents/injection-biomethane-reseau-gaz-rapport.pdf*

[40] *J.-B. Dollé, H. Chambaut, R. Delagarde, N. Edouard, M. Eugene, S. Foray, E. Lorinquer, and V. Manneville, Innovations Agronomiques (Agricultural Innovations) 55 (2017), pages 301-315 "Greenhouse gas mitigation measures in dairy and beef farming".*

https://www6.inrae.fr/ciag/content/download/6072/45051/file/Vol55-22-Dolle.pdf

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[41] *Giger Amélie, Quantification des émissions individuelles de méthane des bovins: du système à l'animal (Individual methane emissions from cattle: from the agricultural system to the animal), the ADEME:* *https://www.ademe.fr/sites/default/files/assets/documents/rapport-greencow-quantification-emissions-methane-bovins-2019.pdf*

[42] *This information was provided to the rapporteur by Mr. Jean-Louis Peyraud (see the list of persons consulted).*

[43] *This information was provided to the rapporteur by Mr. Jean-Louis Peyraud (see the list of persons consulted). In 1985, herds were divided roughly 50/50 between the two types, whereas suckler cows, which are much less efficient than dairy cows, now make up 70% of herds.* *https://www.franceagrimer.fr/fam/content/download/21788/document/plaquette%20des%20chiffres%20cl%C3%A9sBD2.pdf?version=3* *In terms of animal welfare, there is also a considerable difference between suckler cows and dairy cows, as dairy cows are systematically separated from their calves.*

[44] *In 2018, France adopted a national strategy to combat imported products linked to deforestation:* *https://www.ecologie.gouv.fr/sites/default/files/2018.11.14_dp_sndi_mtes.pdf*

[45] *J.M.G. Bloor, P. Jay-Robert, A. Le Morvan and G. Fleurance, "Manure from grazing domestic herbivores: its characteristics and contribution to the functioning of grasslands", INRA Prod. Anim., 2012, 25 (1), pages 45-56* *https://www6.inrae.fr/productions-animales/content/download/6168/86385/version/1/file/Prod_Anim_2012_25_01_4.pdf*

[46] *See reference cited in the previous briefing, page 48, figure 3.*

[47] *https://rewildingeurope.com/areas/greater-coa-valley/*

[48] https://rewildingeurope.com/areas/southern-carpathians/

[49] *Nicole Darmon (2017). "How compatible are the nutritional and environmental qualities of food in France? Benefits of nutrient profiling of foods, nutritional epidemiology and ration modelling", Cholé-doc, No. 154.* *https://hal.archives-ouvertes.fr/hal-01594648/document*