



**HAL**  
open science

## **Environmental footprint of milk and meat from the French cattle sector: progresses since 1990 and future trends to 2035**

Armelle Gac, H el ene Chambaut, Christophe Perrot, Aline Lorilloux, Claire Mosnier, J.-B. Doll e

### **► To cite this version:**

Armelle Gac, H el ene Chambaut, Christophe Perrot, Aline Lorilloux, Claire Mosnier, et al.. Environmental footprint of milk and meat from the French cattle sector: progresses since 1990 and future trends to 2035. LCA Food 2016, 2016, Dublin, Ireland. hal-02742289

**HAL Id: hal-02742289**

**<https://hal.inrae.fr/hal-02742289>**

Submitted on 3 Jun 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destin ee au d ep ot et  a la diffusion de documents scientifiques de niveau recherche, publi es ou non,  emanant des  tablissements d'enseignement et de recherche fran ais ou  trangers, des laboratoires publics ou priv es.

# Environmental footprint of milk and meat from the French cattle sector: progresses since 1990 and future trends to 2035

Gac A.<sup>1,\*</sup>, Chambaut H.<sup>1</sup>, Perrot C.<sup>1</sup>, Lorilloux A.<sup>1</sup>, Mosnier C.<sup>2</sup>, Dollé J.B.<sup>1</sup>

<sup>1</sup> Institut de l'Elevage, 149 rue de Bercy, 75012 Paris

<sup>2</sup> INRA, UMR 1213 Herbivore, F-63122 Saint-Genès Champanelle

\* Corresponding author: Email: [armelle.gac@idele.fr](mailto:armelle.gac@idele.fr)

## ABSTRACT

French cattle farming is committing to take part to national and European mitigation targets. This study combine macro-economics and life cycle assessment to estimate the contributions of the different methods of producing milk and meat at national level and to propose improvement strategies for the future. Analyses of passed production systems, livestock population and agricultural practices allowed us to specify GHG emissions, energy consumption and corresponding footprints, from 1990 to 2010. Various coherent, plausible and contrasted economic scenarios has been chosen to explore the future possible for the horizon 2035. From 1990 to 2010, the cattle sector reduced its emissions and energy consumptions (respectively -10.6% and -22%). This reduction is mainly the result of the decrease in cattle population: improvements in dairy productivity have been followed by a decrease in the number of dairy cows, only partially balanced by an increase of the suckler cows population. Farmers' progress in fertilization management and energy saving also contributed to the overall reduction. This is translated in a reduction of 20% of the carbon footprint (CF) of milk but an increase of 5% in the CF of meat, due to changes in animal products (less dairy cows, more animals from suckler herd, with impact allocation). On the basis of an underlying projection of milk and meat productions for 2035, the future trend would be a stabilization in GHG emissions (+0.5%) and a decrease of energy consumption (-13%) from 2010 to 2035. The CF of milk would reach 0.94 kg CO<sub>2</sub>eq/kg FPCM and CF of beef 14.9 kg CO<sub>2</sub>eq/kg LW. Adoption of additional mitigation techniques would lead to improve both CF of milk and meat by -6% and -13%. Other scenarios explore contrasted situations, on the level of production, as well as on the ways to produce milk and meat. The results should help the sector to make the future stakes their own, in a context of questionings and strong expectations for livestock regarding climate change.

Keywords: climate change, energy, livestock, national level, prospective

## 1. Introduction

With a contribution of 12.6% to the French greenhouse gas (GHG) balance (Dollé et al., 2015), cattle farming is committing to take part to national and European mitigation objectives. This observation is related to the importance of this sector at national level: 1<sup>st</sup> producer of beef and 2<sup>nd</sup> producer of milk in Europe, cattle farms use directly about 40% of the French agricultural area (Perrot et al., 2013) and provide 433 000 direct and indirect employments (Lang et al, 2015).

The French low carbon national strategy launched by the government at the end of 2015, targets a reduction of 12% of the agricultural sector emissions of GHG in 2028 in comparison with 2013 and a reduction of 50% in 2050 in comparison with 1990. In this context, a recent analysis of different scenarios combining GHG mitigation options showed that agriculture and forestry could reduce their GHG by 20% in 2035 (Martin et al., 2015). The scenario approach is a widely used method to explore a highly uncertain future for agriculture (Abildtrup et al. 2006; Audsley et al. 2006; Mandryk et al. 2012) by describing coherent and plausible future states of the world. Concerning the bovine sector, its in the next 20 years will depend on numerous factors including not only the use of GHG mitigation technics, but also other technological improvements, production organizations, population growth and consumer behavior and policy.

The Gesebov project investigated the joint evolution of the dairy and beef cattle sectors in horizon 2035, through contrasted prospective scenarios, and its associated level of GHG emissions and energy consumption in a life cycle perspective, both at farm and national levels. Since emissions of GHG of the bovine sector are first explained by the bovine inventory (Casey & Holden 2006b) and second by the way meat and milk are produced (Monteny et al. 2006; Johnson et al. 2007), Gesebov scenarios have been specifically elaborated to be contrasted in terms of volume of milk and beef produced and technology of bovine production.

This paper focuses on the national level, providing the state of national impacts from 1990 to 2035 and evolution of environmental efficiency at product level. The aim is to imagine how beef and milk would be produced in the future, in different contexts, and to assess how far the simulated scenarios are compatible with climate change mitigation objectives and consumers expectations in terms of environment performance.

## 2. Methods

This study combines economics, including prospective, and a life cycle assessment approach.

Various coherent, plausible and contrasted economic scenarios has been chosen to explore the future possible for the horizon 2035. The trend scenario (S1) is considered as the most probable (from the 2014 perspective). It has been elaborated considering past trends and the most likely evolution of technology and markets. Assumptions are in lines with the previous prospective for beef and dairy production in 2020 (Idele 2014). Alternative scenarios (S2 to S4) have been constructed to explore other plausible futures, considering that new driving forces could be reinforced in future (as a strong growth of world food market, or changes in European social demand for food quality and environmental respect). Those scenarios have been built by expert groups gathering people working in the beef and dairy sectors and researchers. In addition, environmental scenarios have been built, as a declension of S1 and S2, called S1Bis and S2Bis. Those two ones include high investments in GHG and energy mitigation technics, most of them selected in Pellerin et al. 2013. Changes concern herd management (age at first calving, mortality), feeding (use of lipids or nitrates, total crude protein intake management), crop and grassland management (legume fodder, mineral fertilization, simplified cropping practices), manure management especially biogas production, energy consumption reduction, hedges and agroforestry development to enhance carbon storage.

Finally, 6 scenarios are available:

- S1: Trend evolution (raise of milk production, due to increasing global demand, stabilization of beef production)
- S1Bis: Trend evolution and strengthened environmental strategy (*idem* and improvement of practices, including GHG mitigation options)
- S2: Answer to a high global demand (high increase of milk and beef production to satisfy a highly raising global demand)
- S2Bis: Answer to a high global demand and strengthened environmental strategy (*idem* and improvement of practices, including GHG mitigation options)
- S3: Fold on an internal demand which goes upmarket (the production reaches first the demand of national consumers, wanting for products from French and grass based origin, and secondly a decreasing global demand but still for “French quality” products)
- S4: Large drop in consumption and strengthened environmental strategy (decreasing French cattle production because of pressure from citizen and policy makers to reach the GHG mitigation objectives).

The scenarios are mainly driven by the amount and nature of the demand for milk and beef (Table 1): consumption of milk and beef per inhabitant, imports and exports, determine the volumes to be produced, and then the number of animals needed; concerns of consumers and policy makers also influence the type of production systems and practices (degree of efficiency and of intensification at animal and area, use of inputs, etc.).

Description of the bovine French farm in 1990 and 2010 is based on national census data and on technical references from Inosys (national network of about 2000 breeders). The number of dairy cows is distributed through 8 categories described by Ballot et al. (2010) in terms of forage systems, diet and production level; dairy heifers are distinguished in 3 classes, depending on age at first calving; suckler cows are distributed in 3 forage systems (with a gradient in the place of grass and maize); for the 12 other classes of animals dedicated to produce meat (weaners, young bulls, etc.), an average diet is determined.

For each class of animals and each year, or scenario, the diet and indicators such as milk productivity, weight, mortality, duration of fattening, etc. are described. From the diets, we assessed the need of area of grass, maize silage, grain, etc. with a coherence control in 1990 and 2010 to correspond to census data about areas in cattle farms. The need of bought concentrates is also then established. The time spent in grazing pasture and the type of building allowed to determine the manure management system (slurry / farmyard manure) and the amount available for organic fertilization. Data from national census and UNIFA (national union of fertilizing producers) gave the amount of mineral fertilizers used in 1990 and 2010. For 2035, they are determined from plant needs,

and nitrogen inputs by legumes and effluents. In parallel, simulations at farm scale with the Orfee model (Mosnier et al., 205) allowed to validate these assumptions and trajectories.

Table : Main characteristics of the French bovine production in 1990, 2010 and 2035, through the Gesebov scenarios

	1990	2010	S1	S1Bis	S2	S2Bis	S3	S4
Milk consumption (kg/hab)	351.7	311.8	268.2	268.2	295.0	295.0	241.4	214.6
Total milk consumption(Mt)	19.9	19.6	18.4	18.4	20.2	20.2	16.5	14.7
Milk import (Mt)	2.19	5.18	5.00	5.00	6.50	6.50	2.00	1.00
Milk export (Mt)	-6.46	-9.13	-18.67	-18.67	-24.00	-24.00	-7.50	-5.0
Milk production (Mt)	24.19	23.60	32.04	32.04	37.71	37.71	22.03	18.70
Evolution since 1990		1.1%	37.2%	37.2%	61.5%	61.5%	-5.6%	-19.9%
Milk yield (kg / dairy cow)	4 676	6 956	9 093	9 093	9 725	9 725	7 164	8 591
Dairy cows (1000 heads)	5 303	3 716	3 635	3 635	4 020	4 020	3 227	2 290
Beef consumption (kg cwe/hab)	29.8	26.0	21.92	21.92	24.1	24.1	19.7	17.54
Total beef consumption (Mt cwe)			1501.	1501.	1651.	1651.	1351.	
	1 500	1 641	6	6	7	7	4	1201.2
Beef import (Mt cwe)	459.3	411.0	400.0	400.0	500.0	500.0	230.0	200.0
Beef export (Mt cwe)	-844.7	-541.1	-550.0	-550.0	-900.0	-900.0	-390.0	-200.0
Beef production (Mt cwe)	1 903	1 764	1 652	1 652	2 052	2 052	1 511	1 201
Evolution since 1990		-7.3%	-13.2%	-13.2%	7.8%	7.8%	-20.6%	-36.9%
Suckler cows (1000 heads)	3 708	4 179	3 747	3 177	4 640	3 970	2 810	2 510
Stocking rate (heads/ha AA)	1.86	1.91	1.92	1.95	1.89	1.91	1.82	1.80

cwe: carcass weight equivalent

The ClimAgri® tool has been used to assess the GHG emissions and energy consumption of the French bovine farm. It is the national tool to make climate and energy diagnosis for the agriculture and forestry sectors at territory level, taking into account all inputs and direct environmental fluxes, in a life cycle perspective (Doublet, 2011). This tool also provide other helpful indicators such as variation in direct soil organic carbon (under permanent grasslands and hedges) and its potential to compensate climate change (in % of the GHG emission), direct ammonia emissions (kg N-NH<sub>3</sub>/ha of agricultural area, AA) and need of external AA to produce bought feed (in ha imported AA/ ha AA of the French farm).

For the Gesebov project, ClimAgri® was refined. For the animal classes mentioned above, considering their diet and productivity, their enteric emissions and nitrogen excretion were specifically calculated.

The LCA impacts assessed correspond to climate change expressed in kg CO<sub>2</sub>eq, with IPCC 2013, and energy consumption, as Non renewable, fossil expressed in MJ, with the Cumulative Energy Demand 1.8 method. For climate change, emissions of GHG and carbon storage are accounted separately, according to ISO 14067:2013.

Functional units to express impacts on climate change (only GHG emissions) and on energy resource depletion are here one kg of FPCM (fat and protein corrected milk) produced and one kg of LW (live weight) of beef produced by the French bovine farm.

A biophysical allocation, similar to the one applied in the French AGRIBALYSE® program (Koch and Salou, 2015), is here used to share the environmental impacts between milk and meat: the burdens associated to dairy cows are calculated in separate ClimAgri® files and attributed to milk production, while the burdens of all the other bovine animals (including dairy heifers) are attributed to meat production.

### 3. Results

From 1990 to 2010, the cattle sector already reduced its GHG emissions and energy consumptions, respectively of -10.6% and -22% (Table 2). Those reductions are mainly the result of the change in cattle population: improvements in dairy productivity have been followed by a decrease in the number

of dairy cows, only partially balanced by an increase of the suckler cows population. Farmers' progress in fertilization management and energy saving also contributed to the overall reduction. This is translated in a reduction of carbon footprint (CF) of milk from 1.44 to 1.15 kg CO<sub>2</sub>eq./ kg FPCM and an increase in CF of meat from 13.96 to 14.7 kg CO<sub>2</sub>eq./ kg LW (Table 4), due to changes in animal products (less meat from the dairy herd, more from the suckler herd, with longer cycles of production). The intensification of bovine production (increase of productivity and stocking rate, Table 1) also led to decrease the areas of permanent grasslands and the subsequent carbon storage (-6%, Table 3).

The future trend for 2035 would be a total stabilization in GHG emissions and an extra decrease of energy consumption comparing to 2010 (respectively +0.5% and -13%). Gains in productivity, efficiency and improvements of practices are still possible. The CF of milk would reach a decrease (-19% since 2010) and CF of meat would be stabilized (+1%). Adoption of additional mitigation techniques in the scenario S1Bis would lead to improve both CF of milk and meat, as well as the national GHG and energy balance of the cattle sector. However, in those scenarios, attention must be paid on the risk of continuing decreasing of carbon storage (-20% and -13% for S1 and S1Bis). At the same time, the sector would become less self-sufficient in concentrate feed.

In the scenario S2, the high increase in production induces more GHG for the French cattle farm, but a similar energy consumption, thanks to gains in productivity, also allowing to reduce footprints. The S2Bis leads to a higher environmental efficiency, almost in the same proportion as between S1 and S1bis. The loss of carbon storage, due to conversion of grasslands to crops, is the weak point of this scenario (Table 3).

Decrease of production and more extensive grass-based systems in S3, would lead to significantly decrease GHG and energy consumption. From the products point of view, footprints are still improved. However, for milk, reductions in footprints are here the weakest. Nevertheless, this does not consider the higher carbon storage potential (Table 3). Ammonia emissions are here significantly decreased, due to a decrease of the stocking rate (Table 1) and a higher use of pasture (less manure in buildings). Feed self-sufficiency is significantly improved.

In S4, the higher decrease in national GHG emissions and fossil energy use is directly linked to the fall of milk and beef production. Gains in footprints are quite high (similar to S1Bis or S2 for milk and to S3 for meat), thanks to a mix of extensive grass-based systems and of very efficient herd management, both in beef and dairy production. It allows ammonia reduction and feed self-sufficiency. Grasslands, with their capacity to compensate GHG emissions, are here preserved (compensation increases by 27%).

Table 2: Total GHG emissions and energy consumptions (direct + indirect) of the French cattle sector from 1990 to 2035 through the Gesebov scenarios.

	1990	2010	S1	S1Bis	S2	S2Bis	S3	S4
GHG (Mt CO <sub>2</sub> eq.)	83.15	74.33	74.67	66.75	87.89	77.97	60.94	47.71
Energy (GJ)	193	150	131	105	149	115 914	90 150	71 127
	846	575	194	080	561			

Table 3: Additional direct environmental indicators of the French cattle sector from 1990 to 2035 through the Gesebov scenarios.

	1990	2010	S1	S1Bis	S2	S2Bis	S3	S4
C compensation (%)	16%	15%	12%	13%	10%	12%	16%	19%
kg N-NH <sub>3</sub> /ha	35	33	34	32	35	32	28	27
Imported /French AA (%)	32%	31%	33%	34%	26%	27%	24%	24%

Table 4: Environmental impact of milk and beef in France from 1990 to 2035 through the Gesebov scenarios

	1990	2010	S1	S1Bis	S2	S2Bis	S3	S4
kg CO <sub>2</sub> eq. / kg FPCM	1.44	1.15	0.94	0.88	0.89	0.82	0.98	0.89
MJ / kg FPCM	5.25	3.66	2.17	1.94	1.92	1.65	2.16	1.99

kg CO <sub>2</sub> eq. / kg LW	13.96	14.70	14.87	12.87	14.54	12.66	14.29	14.22
MJ / kg LW	19.34	20.05	20.49	14.33	20.71	14.43	15.49	15.49

FPCM : Fat and Protein Corrected Milk. LW: live weight

#### 4. Discussion

The prospective Gesebov scenarios are voluntarily contrasted to help the cattle sector to think about the different possible futures and to decide the actions they want to invest in. One have to keep in mind that the reality will be somewhere in between all of them.

The environmental impacts obtained for 2010 are comparable to those from the AGRIBALYSE® French LCI database ([www.ademe.fr/agribalyse](http://www.ademe.fr/agribalyse)) for the average French milk (0.89 kg CO<sub>2</sub>eq/ kg FPCM, 2.17 MJ/ kg FPCM) and the average French beef cattle (11.93 kg CO<sub>2</sub>eq/ kg LW, 19.60 MJ/ kg LW) at farm gate. For AGRIBALYSE®, optimized systems, described in case studies, were used (Koch and Salou, 2015), while here the data used allowed to draw a more realistic picture of the French cattle farm. That can explain higher footprints. The detailed use of ClimAgri® (instead of using default values per head for enteric methane or nitrogen excretion) gave a valuable precision, needed when considering a sector with a high contribution to the national GHG emissions. It also allowed sensitivity of the results through scenarios. One important point of the ClimAgri® that should be improved in the future, is the accounting for soil carbon dynamics. Even if the method provide accounting for carbon below permanent grasslands and hedges, improvements are needed to also consider temporary grasslands and crops. It would help considering the whole picture of the contribution of the cattle sector to climate change and to identify strength and weakness, especially between scenarios with different use of soils (grains and forages vs grass). Ongoing programs, focusing on how to account for soil carbon in LCA, should also help to improve this point in the future.

Considering the national targets for GHG mitigation in the future, the scenarios S3 and S1Bis would met the objectives at mid term (-12% between 2013 and 2028). For the objective at long term (-50% between 1990 and 2050) only the scenario S4 would be able to reach it. This should make become aware of possible split-over effects. What are the other environmental impacts of the sector (such as effects on biodiversity, water quality, etc.)? If cattle activity declines, what would become of the liberated areas (agricultural production or not, which practices, which loss of carbon)? If the global demand is raising but French activity is declining, reducing its export, the production should be transferred in other countries in the world. Then, we should question on the new carbon footprint of the milk and beef done elsewhere (which environmental efficiency?). And last, but not least, social and economic impacts of those scenarios, especially in terms of employment, were not here considered. This lets open a wide and interesting field of study, which should help considering futures for the cattle sector, not only from a carbon footprint point of view.

#### 5. Conclusions

Analyses of French cattle production systems, livestock population and agricultural practices allowed us to specify GHG emissions, energy consumption and corresponding footprints, from 1990 to 2035. Results show that the sector already enhanced its environmental efficiency and that improvement strategies are still available for the future. Producing milk and beef is compatible with taking care of climate and energy resources, as long as the mitigation strategies are integrated in the systems.

One have to keep in mind that scenarios are prospective and not predictive of the future. The results should now help the sector to make the future stakes their own, in a context of questionings and strong expectations for livestock regarding climate change.

#### 6. References

Abildtrup, J., Audsley, E., Fekete-Farkas, M., Giupponi, C., Gylling, M., Rosato, P., Rounsevell, M. 2006. Socio-economic scenario development for the assessment of climate change impacts on

- agricultural land use: a pairwise comparison approach. *Environmental Science & Policy* 9, 101-115.
- Audsley, E., Pearn, K.R., Simota, C., Cojocaru, G., Koutsidou, E., Rounsevell, M.D.A., Trnka, M., Alexandrov, V. 2006. What can scenario modelling tell us about future European scale agricultural land use, and what not? *Environmental Science & Policy* 9, 148-162.
- Ballot, N., Picard, S., Brunschwig, P. 2010. Observatoire de l'Alimentation des vaches laitières, CNIEL, Institut de l'Elevage, Paris. p 38.
- Casey, J., Holden, N. 2006b. Quantification of GHG emissions from suckler-beef production in Ireland. *Agricultural Systems* 90, 79-98.
- Dollé, J-B., Moreau, S., Brocas, C., Gac, A., Raynal, J., Duclos, A. 2015. Elevage de ruminants et changement climatique, Institut de l'Elevage, Paris. p 24.
- Doublet, S. 2011. CLIMAGRI : Guide méthodologique et guide des facteurs d'émissions et références utilisées. ADEME, Angers. p 190.
- IDELE, 2014. Quelle production française de viande bovine à l'horizon 2020 ? Dossier Economie de l'Elevage n°450. Institut de l'Elevage, Paris. p 24.
- Johnson, J.M.F., Franzluebbers, A.J., Weyers, S.L., Reicosky, D.C. 2007. Agricultural opportunities to mitigate greenhouse gas emissions. *Environmental Pollution* 150, 107-124.
- Koch, P., Salou, T. 2015. AGRIBALYSE®: METHODOLOGY, Version 1.2, February 2015. Ed ADEME. Angers. France. p 384. Available at: [www.ademe.fr/agribalyse-en](http://www.ademe.fr/agribalyse-en).
- Lang, A., Perrot, C., Dupraz, P., Trégaro, Y., Rosner, P.M. 2015. Les emplois liés à l'élevage français. GIS Elevage Demain, Paris. p 444.
- Mandryk, M., Reidsma, P., van Ittersum, M.K. 2012. Scenarios of long-term farm structural change for application in climate change impact assessment. *Landscape Ecology* 27, 509-527.
- Martin, S., Eglin, T., Bardinal, M. 2015. Analyse comparative de scénarios de lutte contre le changement climatique pour l'agriculture à l'horizon 2035, Rapport final. ADEME. p 38.
- Monteny, G.-J., Bannink, A., Chadwick, D. 2006. Greenhouse gas abatement strategies for animal husbandry. *Agriculture, Ecosystems & Environment* 112, 163-170.
- Mosnier, C., Duclos, A., Lherm, M., Lelyon, B., Gac, A. 2015. Orfée : un modèle bioéconomique d'exploitation pour simuler la production, les résultats économiques et les émissions de gaz à effet de serre des exploitations bovines. *Rencontres Recherche Ruminants*, 22, 89.
- Pellerin, S., Bamière, L., Angers, D., Béline, F., Benoît, M., Butault, J.P., Chenu, C., Colnenne-David, C., De Cara, S., Delame, N., Doreau, M., Dupraz, P., Favardin, P., Garcia-Launay, F., Hassouna, M., Hénault, C., Jeuffroy, M.H., Klumpp, K., Metay, A., Moran, D., Recous, S., Samson, E., Savini, I., Pardon, L. 2013. Quelle contribution de l'agriculture française à la réduction des émissions de gaz à effet de serre ? Potentiel d'atténuation et coût de dix actions techniques. Synthèse du rapport d'étude. INRA, Paris. p 92.
- Perrot, C., Barbin, G., Bossis, N., Champion, F., Morhain, B., Morin, E. 2013. L'élevage d'herbivores au Recensement agricole 2010. Cheptels, Exploitations, Productions. Dossier Economie de l'Elevage n°440-441. Institut de l'Elevage, Paris. p 95.