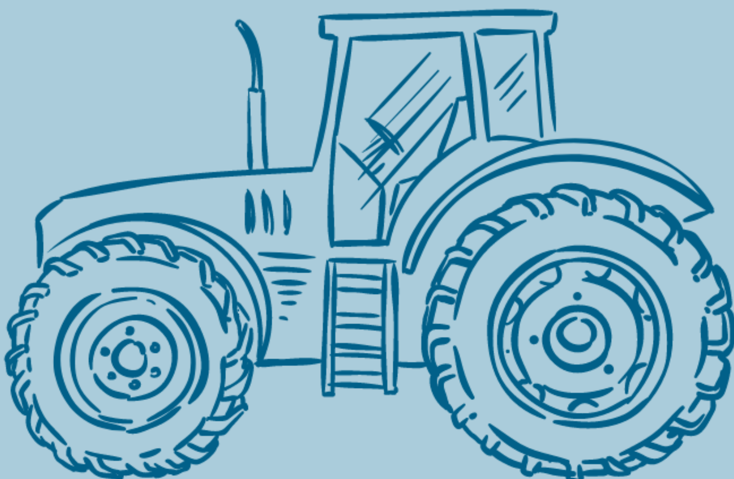
FARM EUROPE

Summary report

SUSTAINABLE PRACTICES TO REDUCE GHG



EMISSIONS ON CATTLE FARMS

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Farm Europe is a multi-cultural think tank founded in 2014 that aims to stimulate thinking about the EU's rural economies. The think tank, focuses on agriculture and food policies, particularly the Common Agricultural Policy (CAP), but also food standards, the food chain, environment, energy and trade issues.

LIST OF ABBREVIATIONS

AEI : Agroecological Infrastructure

CIV : Calving interval

DM : Dry Matter

EU : European Union

FAO : Food and Agriculture Organization

FU : Forage Unit

GOS : Gross Operating Surplus

GRFP : Gross raw flesh production

Kgrf : kilograms of raw flesh

LSU : Livestock Unit

MWU : Man Work Unit

SES : Socio-Ecological System

STS : Socio-Technical System

UAA : Utilized Agricultural Area

Overview of cattle farming in Europe

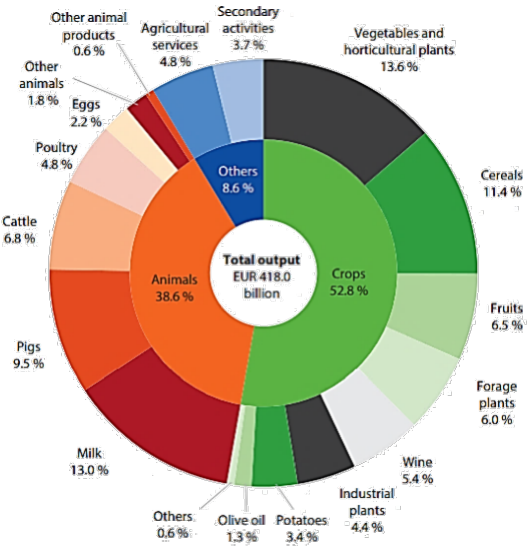
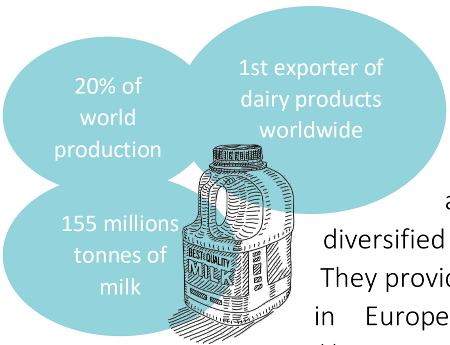


Figure 1: Contribution of each agricultural sector to total agricultural production (Eurostat, 2019a, 2019b)

Livestock production accounts for almost 40% of agriculture in Europe (Figure 1) (Dumont et al., 2016; Rattin, 2000). Cattle farms account for 23% of the European UAA (Useful Agricultural Area). 87 billion (European Commission, 2018b, 2020b, 2020a)(European Parliament, 2021c, 2021a, 2021b).

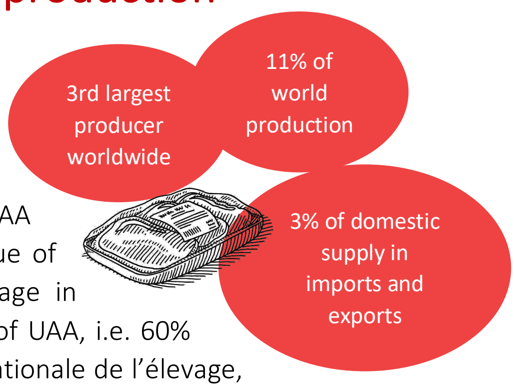
Patterns in the EU cattle sector at farm level vary greatly from region to region. The sector is marked by a deep North/South divide. 49% of dairy farms are located in the North of the EU (Eurostat, 2020). France (23.5%), Germany (15.1%), Spain (8.6%), Ireland (8.5%), Italy (8.3%) and Poland (8.1%) have ¾ of the number of cattle in the EU (in LSU, Large Livestock Unit) (European Commission, 2020a; Eurostat, 2021b).

Milk production



Specialized dairy farms account for 23% of total LSU and produce 78% of cow's milk volumes. They employ 14% of European farm workers, hold 13% of the UAA and use 25% of the forage area. They are important in Ireland (35% of the country's LSU), Germany (35%) and the Netherlands (32%). France and Poland are characterized by diversified polyculture-livestock farms. The structures are mainly family-owned. They provide a limited number of jobs: 1.60 MWU (Man Work Unit) on average in Europe (Chatellier & Dupraz, 2019a)(European Dairy Association, 2020)(Eurostat, 2021a; Institut de l'élevage et Confédération nationale de l'élevage, 2019)(Pour une autre Pac & Heinrich-Böll-Stiftung France, 2019).

Meat production



Specialized meat farms account for 16% of the EU's total LSU, 7% of employment and 1% of the UAA. The structures are family-owned (1.33 MWU on average in the EU). They are larger in area in France (110 hectares on average) than in Ireland (41 hectares) and Poland (23 hectares). They are rather extensive with 1.08 LSU per ha of UAA on average in the EU except in the Netherlands. The annual value of agricultural production (excluding direct aid) amounts, on average in Europe, to 42 800 euros per MWU and 1 140 euros per hectare of UAA, i.e. 60% below that of dairy farms (Institut de l'élevage et Confédération nationale de l'élevage, 2019; Lherm, Agabriel, & Devun, 2017) (Chatellier & Dupraz, 2019a)(Pour une autre Pac & Heinrich-Böll-Stiftung France, 2019).

Breeding challenges

Cattle farming contributes to the creation of wealth and employment in the EU. It contributes to public and economic goods and to the vitality of the territory via provisioning, cultural, regulatory and support services, which are 'direct and indirect contributions of ecosystems to human well-being' (de Groot et al., 2010) (Lasseur et al., 2019). However, it is also subject to climatic and sanitary hazards, market risks, as well as institutional, financial, legislative and human risks. (Dedieu et al., 2008; Rigolot et al., 2019). Table 1 presents a summary of the impacts and contributions of cattle farming (Donnars, Dumont, & Dupraz, 2019).

Table 1: Possible impacts and contributions of cattle farming according to (Donnars et al., 2019)

Domains	*Criteria*	*Indicators*	
		Impacts + and Contributions	*Impacts - and Challenges*
ENVIRONEMMENT	Material and energy flows	Resource saving, recovery of co-products and waste: biogas production.	Input consumption, local or imported pressures. The EU imports 70% of oilseed protein mainly from Argentina and Brazil (FAO, 2017).
	Biogeochemical cycles	Soil fertility, water quality.	Waste, pollution transfers (FAO, 2017).
	Water, air and soil pollution	Low environmental disturbance.	Degradation and contamination of water, soil and air.
	Climate change	Carbon storage through grasslands: the transition from cultivated soil to grassland allows an average of 40% carbon sequestration in soils (i.e. 920 kg C/ha/year) (Dolle et al., 2013; TERRA, 2019).	Emissions from the European herd are between 630 and 863 Mt CO2eq, i.e. 12 to 17% of the total emissions of the EU27. Emissions are between 14.2 and 17.4 kg CO2eq/kg product in Austria and the Netherlands. They are above 40 kg CO2 eq/kg product in Cyprus and Latvia (Weiss & Leip, 2012) (Thomassen et al., 2008) (D. O'Brien et al., 2020).
	Biodiversity	Habitat heterogeneity, species richness in grasslands, rangelands, hedgerows (Lasseur et al., 2019).	Low biodiversity of farm animals, loss and selection of wild biodiversity.
	Land use	Maintenance of meadows, hedgerows, wetlands, mountain pastures and Mediterranean rangelands.	Degradation of potential, conflicts with other uses (nature reserves, urbanization). Requisitions 10% of UAA for grazing, about 60% of cereal areas for feed. Livestock density index reached 0.8 LSU per ha UAA in 2016 (Eurostat, 2019b).
ECONOMY	Production	Wealth creation, high technical and economic performance, quality products (non-GMO, organic): +10% in 2030 in the European Union (European Commission, 2021b; OCDE & FAO, 2019).	Economic crisis, deteriorating incomes, low competitiveness; Decline in meat consumption in the EU (68.7 kg to 67.6 kg retail weight per capita by 2030) The dairy herd could be reduced by 7% to 19.2 million head (OCDE & FAO, 2019).
	Employment	Job creation and professional skills.	Decline in the number of farmers, difficult working conditions.
SOCIO-CULTURAL ISSUES	Values, heritage	Gastronomy, know-how, landscapes, tourism, identity and guarantee of quality, recognition of know-how specific to certain regions (PGI, PDO) (Donnars et al., 2019).	Depreciation and questioning of farming practices, standardization, loss of skills.
	Ethics	Animal welfare, good image of the breeder, the breeding and the sectors.	Animal mistreatment and suffering, poor image of farmers, livestock farming, sectors and products.
HEALTH	Nutritional composition and consumption	Quality animal proteins, diversified foodstuffs.	Excessive levels of saturated fatty acids and omega-6, excessive meat consumption, antibiotic resistance, drug and biocide contamination due to residues in soil and animal products.
	Animal health	Favored by the robustness of the animals and animal welfare.	Incidence of zoonoses, human and animal health costs, production losses (Carpio, 2021; European Commission, 2020b, 2021a).

Study of practices

Faced with these challenges, the overall challenge for cattle farming is to establish resilient and sustainable systems capable of reconciling economic and environmental performance and meeting society's expectations (product quality, animal welfare) (Lasseur et al., 2019). Only the practices selected from all the practices studied are presented in this report (European Commission, 2021c).

The data are from scientific studies carried out at the farm level in the EU. The quantitative data provide orders of magnitude and are to be seen in the context of the studies.

Environmental Aspect

Most of the figures come from the life cycle assessment (LCA) method carried out on the farm (Brocas & Dollé, 2018; CAP2ER, 2013; Internation Standard Organisation, 1997). Other methods also exist (Donnars et al., 2019). 4 indicators were considered:

- *Abiotic depletion:* It accounts for the availability of abiotic resources (all physico-chemical factors) of the ecosystem in kg antimony equivalent (kg Sb eq).
- *Photochemical oxidation:* It measures the amount of photochemical oxidants formed from the release of nitrogen and hydrocarbons under the action of sunlight.
- *Acidification:* It assesses the accumulation of ammonia (NH_3), nitric oxide (NO) and sulphur dioxide (SO_2) in the air.
- *Eutrophication* : It reflects the loss of nitrogen and phosphorus (CAP2ER, 2013; Université de Lorraine, 2013).

Climatic aspect

The production of three gases has been studied:

- *Carbon dioxide (CO_2):* The impacts related to CO_2 are mainly due to the removal of carbon from the soil. The other source is the use of fossil carbon.
- *Methane (CH_4):* A greenhouse gas 25 times more powerful than CO_2, it is the most problematic on the farm. It is associated with anaerobic fermentations.
- *Nitrogen (form N_2O):* It is 296 times more powerful than CO_2. The nitrogen cycle is completely modified by livestock farming. The use of proteins in cattle feed and fertilization are responsible for these emissions. The challenge is to maximize the yield of metabolizable proteins and reduce degradability in ruminant feed to reduce them.

Economic aspect

It accounts for the costs and benefits associated with its implementation of the practice.

Social Aspect

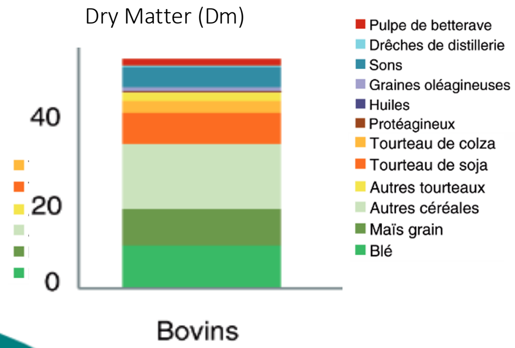
It highlights the ease of carrying out the practice for the farmer and at the level of the EU. The results presented are based on studies conducted with European cattle farmers and use the sociological concepts of *Socio-Ecological System (SES)* (Liu et al., 2007), *Adaptive Cycle* (Holling, 2001), *Socio-Technical System (STS)* (Sarrazin, 2016), *Theory of Action* (Bourdieu, 1979), *Socio-Technical Imaginary* (Korea Author, Jasanoff, & Kim, 2009), *Concept of Social Representation* (Jodelet, 2003), *Theory of Planned Behaviour* (Ajzen, 1991) and *Sociology of Networks* (Compagnone, 2019).

Finally, the last part of the report presents the obstacles and levers to the promotion of these practices on a European scale.

FEED

Feed contributes up to 36% of GHG emissions in suckling farmers and 27-38% of nitrous oxide emissions in dairy farming (Dolle et al., 2013; Doreau et al., 2011; Drews et al., 2020; Guerci et al., 2013; Nunes et al., 2020; Donal O'Brien et al., 2014; Thomassen et al., 2008). The quality of the fodder given to the animals influences CH_4 production and emissions related to enteric fermentation as well as nitrogenous discharges (Nature-Québec, La-Coop-fédérée, & Fédération-des-producteurs-de-porcs-du-Québec, 2011). Variations in feeding exist in the EU depending on regional specificities (UAA, crop rotation, climatic conditions), the age of the animals and the system Dronne (2019).

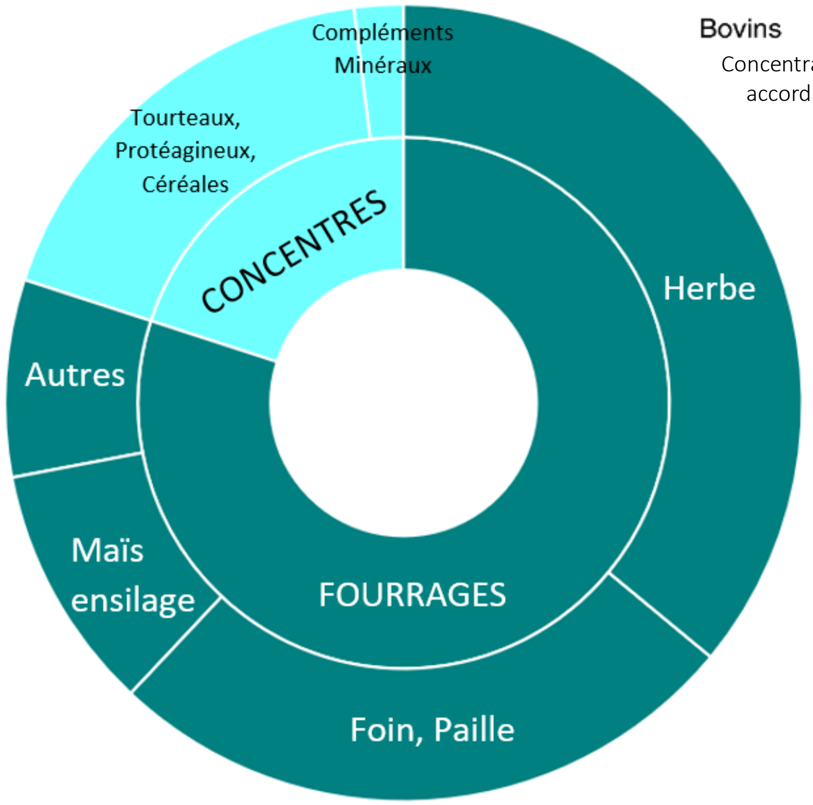
TYPES



Concentrates used in the EU-27 in 2009 according to (Donnars et al., 2019)

COST

French average for conventional farming 2009/2010: 60€/1000L (Seenovia, 2021)



COST

Average for conventional breeding in France 2009/2010: 78€/1000L including structural costs (Seenovia, 2021)

PRODUCTION

Mostly France (16%) and Germany (13%) (Dronne, 2019)

Figure 2: Average ration composition of a dairy/lactating cow in a conventional system in France (Devun, Brunschwig, & Guinot, 2014; DUFRASNE, Christine CUVELIER, 2012)

Protein makes up 35% of the EU's animal diet. The protein leaders are the Netherlands (60%), Spain (59%), Italy (55%), Germany (38%) and France (33%) (Dronne, 2019). The most protein-rich and commonly used grains are soybean, lupin, faba bean, pea and cereals (A. Voisin, 2020). Soy completes 18% of rations on average across the EU (Dronne, 2019; Eurostat, 2021c). The EU has the largest carbon footprint per unit of imported soybeans (0.77 tCO2eq/t) (Espagnol et al., 2020; Karlsson, Parodi, van Zanten, Hansson, & Röös, 2021; Wilfart et al., 2018).

Management of concentrates and feed supplements

P1: Adjusting/reducing the protein level in the ration

Reduction of eutrophication and acidification effects (Broderick, 2018; Cederberg & Mattsson, 2000)

Reduction of net carbon footprint by up to 5-8% (D. O'Brien et al., 2020)
Annual reduction of -241 to -295 kgCO2eq/animal/year (Dollé et al., 2011; Doreau et al., 2011)
Variable impacts depending on the type of farm and the source of protein (Brizga, Kurppa, & Heusala, 2021; Tullo, Finzi, & Guarino, 2019; Vries & Boer, 2010; Weiss & Leip, 2012).

Figure 3: Global warming potential in kg CO2eq/kg dry matter by type of protein used (D. O'Brien et al., 2020)

Average gain is 11.6€/animal/year (Pellerin et al., 2013)
No difference in growth and feed conversion rates (Kebreab, France, Beever, & Castillo, 2001; Kebreab et al., 2010)

Is part of the desire for food autonomy and independence (d'Alteroche, 2013)

P2: Replacement of soybean meal with rapeseed meal

No major environmental interest for (Lehuger, Gabrielle, & Gagnaire, 2009) but they underestimate the impacts of soybean cultivation on sensitive lands in South America (deforestation).
Allows for the enhancement of European agricultural land at risk from land artificialization (EEA, 2019).

Reduction of the net carbon footprint of products by 3 to 7% (Dollé et al., 2011)

Economically attractive: 240€/T against 360€/T for soya (Synagri, 2013)

Is part of the desire for food autonomy and independence (d'Alteroche, 2013)
Specifications limit the maximum quantities of feed/cow/year
Re-territorialization of protein production (Nutritionnistes De meuh en mieux, 2020)

P3: Inclusion of algae in the ration

Controlling effluent-related algal blooms
Risks related to cultivation:

- Competition with other sectors for production areas (shellfish farming)
- Possible bacterial and viral contamination (Cottier-Cook et al., 2016)
- Energy intensive production (Taelman, De Meester, Van Dijk, Da Silva, & Dewulf, 2015)

Asparagopsis taxofirmis: 80% reduction in CH_4 emissions in beef cattle (Honan, Feng, Tricarico, & Kebreab, 2021; Roque et al., 2021)
Asparagopsis Armata à 0,5%: 26.4% reduction in enteric CH_4 production in beef cattle (Morais et al., 2020)

Asparagopsis sp:

- Reduction of production cost due to improved feed conversion
- For 1000 head of suckling cattle/year: potential feed cost reduction of €34 098 to €73 846 depending on the dosage (low or high) of algae (Morais et al., 2020; Roque et al., 2021; Taelman et al., 2015)
- Algae flour already in use but algal extracts still inaccessible (Le Blé & Morice, 2013)(Le Blé & Morice, 2013)

Cultural blockage: highly developed in Asia but little promoted in Europe
Great diversity of algae can make their use complex (Le Blé & Morice, 2013)

P4: Use of fat in the ration

Beneficial for acidification
Possible impact on eutrophication and land use (IDELE, 2011)

Flax	-14% to -29%
Coco	-28% to -35%
Canola	-22% to -32%
Sunflower	-17% to -24%

Table 2: Potential to reduce enteric CH4 emissions (Arndt et al., 2020; Doreau et al., 2011; Hadipour et al., 2021; Honan et al., 2021; Jouany et al., 2008)

Annual mitigation potential: 1.89 Mt CO_2 eq/year on the farm (Pellerin et al., 2013)
Potential to reduce the overall net carbon footprint of products by 3 to 7%, depending on the type of fatty acid (Dollé et al., 2011; Nature-Québec et al., 2011; D. O'Brien et al., 2020)

Additional costs for young cattle: 11.6€/animal/year for dairy and 6.8€/animal/year for suckler (Pellerin et al., 2013). The cheapest fats are rapeseed and flax (Arndt, Mcclelland, Oh, & Bayat, 2020).

Requires adaptation of the diet (IDELE, 2011).

Forage and pasture management

P1: Increase grazing time

Minimizes soil destruction, nitrogen and carbon losses and nitrate leaching (Hennessy, Delaby, van den Pol-van Dasselaar, & Shalloo, 2020) and maintains biodiversity (Fourrage mieux, 2015; Lambert, Personeni, Amiaud, & Bonis, 2010)

Carbon storage: 500 kg/ha of grassland/year (Herb'actifs, 2021)
Enteric CH_4 emissions: -12% to -16% daily
GHG emissions: -3% to -10% of net carbon footprint (Arndt et al., 2020; Hennessy et al., 2020; Lambrecht, Bonestebe, Lomelet, Le Gac, & Velghe, 2020d; D. O'Brien et al., 2020)

6.4% increase in GOS (Gross Operating Surplus)(Lambrecht et al., 2020d)
Savings on feed, concentrates and better products (Hennessy et al., 2020; Wilkinson, Lee, Rivero, & Chamberlain, 2020).
Average gain of 11.6€/dairy cow/year (RMT Elevage et Environnement, 2019a).

Positive social representation: landscape, animal welfare
Land limitations: proximity to grasslands
Can lead to loss of time in caring for animals in large herds
Fear of risk: change of system
Food autonomy WQ (Calvez, 2007; Donnars et al., 2019; Le Blé & Morice, 2013; Petit, 2017; van den Pol-van Dasselaar, Hennessy, & Isselstein, 2020)
Over and under grazing (Chambre d'agriculture de l'Aude, n.d.)

P2: Improving forage quality with legumes: field pea, vetch, faba bean, clover, lupin

No-till double cropping of meslin between cereals and maize provides permanent soil cover
Breaks pest cycles, reduces nitrate leaching (Lehuger et al., 2009)
N_2 fixation
Pea production on the farm: Reduction of acidification (-17%) and eutrophication (-12%) (A. S. Voisin et al., 2014)

Reduction of about 18g of enteric CH_4/kg of DM ingested (389g/day vs. 459g/day of CH_4) with the addition of legumes in the ration (Baumont, Bastien, Férard, Maxin, & Niderkorn, 2016)
Reduction of CO_2 emitted during fertilizer production and N_2O emitted during fertilizer application (A. S. Voisin et al., 2014)
N_2O emissions measured on association grasslands are lower than those measured on grasslands (0.2 vs 1.3% N)
Possible 15% reduction in carbon footprint (Dollé et al., 2011)

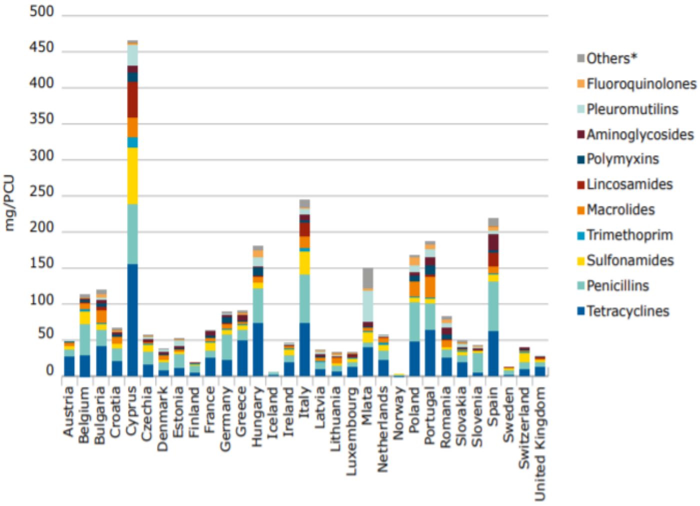
Reduction of nitrogen fertilization and purchase of concentrate: forages rich in fiber and nitrogen
Red clover and alfalfa: farm results can be improved by 2,000€/year (Guillaume, 2015)(Gautrais, 2018)
Ration cost with meslin is around 75 €/1000 liters (Vergonjeanne, 2019)
+ 10% increase in disposable income according to simulations (IDELE, 2020b)

Autonomy of the farm (rate of purchased concentrates < 10%) (RMT Elevage et Environnement, 2019b)
Increases the amount of work
Securing stocks (IDELE, 2020b)
Management difficulties depend on the plant:

- Perenniality of white clover in grasslands and over-seeding of white clover in established grasslands, red clover is less demanding
- Faba bean: easy to use
- Lupin: a delicate crop because of its high soluble nitrogen content
- Pea: its high starch content limits it to finishing (Mathioux, 2020; Vergonjeanne, 2019)

ANIMAL WELFARE AND HEALTH

Animal welfare is defined in terms of its physical, psychological well-being and its ability to perform its natural behaviours (CIWF, n.d.). Animal welfare regulations are set in the EU to limit distortions but divergences exist between countries (Roguet, Neumeister, Magdelaine, & Dockes, 2017). Improving the life span of a dairy cow from 3.02 to 3.5 lactations would reduce methane emissions by 3% and limit medical costs (Shields & Orme-Evans, 2015). The average veterinary cost for French cattle farms is around €48/LSU but varies according to the degree of antibiotic use and treatment on farms and in Europe (Institut de l'élevage, 2010). For Europe as a whole, these costs represented about €6.5 billion in 2019 (Cook, 2020). The reduction of antibiotics in the cattle industry is also a major challenge in the face of problems of antibiotic resistance (Beloeil et al., 2020)(Sanders, Perrin-Guyomard, & Moulin, 2017).



Sales of antibiotics for animal production in 31 European countries (in mg/Population Correction Unit) in 2018 according to (European Medecines Agency, 2021)

P1: Use of clays: as a poultice or ingested

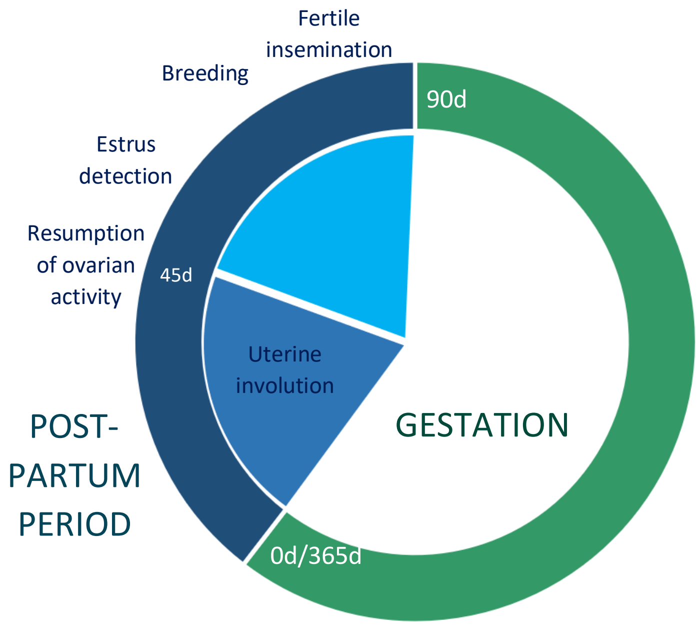
No significant negative environmental consequences
Possibly polluted with metals potentially toxic to animals or the environment (Laval, 2020; Vignaud, 2020)

Optimize ruminal digestion and decrease enteric fermentation
Bentonite in ruminant diets: possible decrease in the molar proportion of methane from -6.7% to -7.9% (Kaboul & Ouachem, 2012)

Affordable: €5.50/kg or an average of €400/cow/year
Pro-digestive properties that increase feed efficiency (Conseillers techniques OPTIVAL-OXYGENE, 2015; Duval, 1993; Kaboul & Ouachem, 2012)

Requires training and apprenticeship to implement the practice
Limited herd size as practice is done individually
By ingestion, the effect depends on the time of addition (Duval, 1993)
Depends on the rest of the ration: the results on methane reduction are mainly observed in farms where the feed is rich in concentrate and silage (D. Ouachem & F. Nouicer, 2006; Ouachem, 2011)

REPRODUCTION



The issues vary depending on the sector, but the action plan is the same: ensure the birth of calves, choose replacement heifers and cull unproductive cows (Nature-Québec et al., 2011). The cow's food and health needs increase during gestation (9 months) (la-Viande.fr, 2021). The average age at calving is 36 months.

Figure 5 : Reproduction cycle of a cow (Reprodaction, n.d.)

P1: Maintain a calving interval (CIV)

No effects identified

Dairy CIV reduction : reduction in carbon emission intensity per cow and per kg of milk produced (Bell, Eckard, Haile-Mariam, & Pryce, 2013)
Reduction of CIV in suckler farming : gaining 15 days the CIV (390 to 375) reduces the net carbon footprint of the farm by 2.2% (13.7 vs. 13.4 kg CO2eq/gross raw flesh production (GRFP) (Lambrecht, Bonestebe, Lomelet, Le Gac, & Velghe, 2020c)

Gain in feed efficiency and productivity (Veron, 2021)
Reduction of CIV in suckler farming: gaining 15 days the CIV allows to increase the GRFP by 6 kgrf/LSU (Lambrecht et al., 2020c)

- → Reduction from 400 to 380 days: gains around 5.3€ to 22.5€/cow/year
- → Reduction from 420 to 400 days: 4.8€ to 20.3€/cow/year (Citerne, 2013)

CIV reduction in dairy farming to 390 days: gain between 3 and 4€/day/cow (Mahey, 2019)

Facilitates calving and reduces the risk of infections
Requires attention to good husbandry conditions: housing and vitamin D and adaptation of rations (Lambrecht et al., 2020c)
Spreads out the work with peak periods (IDELE, 2020b)

P2: Reduction of the age of first calving

No effects identified

Strategy 1 Iso LSU

The same number og LSU is kept and the number of calvings is changed. For a calving at:

- 30 months: -8% of net carbon footprint
- 24 months: -14% of net carbon footprint (Breton et al., 2020)

Strategy 2 Iso calving

Keep the same number of calvings and reduce the number of LSUs. For a calving at:

- 30 months: -5% of net carbon footprint
- 24 months: -4% of net carbon footprint (Breton et al., 2020)

Reduced expenses (Nature-Québec et al., 2011)
Increase in live meat production
At 30 months: GOS +11%, at 24 months : GOS +6%.

At 30 months, there is no difference in the zootechnical management, it is simply necessary to be rigorous on the reproduction periods
At 26 months, management is demanding, it is easier to turn to a calving isolation strategy (reduces the number of heads to manage) (Breton, Doal, Guy, Halter, & Velghe, 2020)

P3: Selection practices

Variable depending on the breed selected, may allow a reduction in impacts (ACTA, 2020; Le Roy, Ducos, & Phocas, 2019; Schibler, 2019; WHO Regional Office for Europe, 2019)
Dual-use breed selection could reduce total land use by 2% (Samsonstuen et al., 2020)

Possible reduction of up to 30% of CH_4 emissions per animal (Hadipour, Mohit, Kuhi, & Hashemzadeh, 2021; Martin et al., 2020)

Improvement in quality, quantity of goods produced and herd performance (Magne et al., 2019)
Charolais selection: Reduction of feed costs to 0.47€/kg of meat produced (Herd Book Charolais, 2021)

Disease resistance: facilitates herd management (Shields & Orme-Evans, 2015) (Froidmont, 2018)
Can cause breed-related difficulties: example of reproduction in the culard breed
Selection is carried out by the breeder (choice of sires) or in the laboratory (genetic selection) (Berodier, 2020; Griffon et al., 2017)
Different perception depending on the type of selection (production, morphological, social or functional aptitudes): example of reintroduction of local breeds promotes the image of the terroir, quality, identity and tradition
Selection of hornless cattle: Animal welfare by avoiding dehorning (Etienne, 2019)

FINISHING AND PRODUCTIVITY

A high finishing rate is necessary for the productivity of the farm. Finishing cull cows provides a significant gain in gross live meat production and reduces GHG emissions by 6% (DS, 2021).

P1: Increasing the finishing rate in beef cattle

No effects identified

Reduction of net carbon footprint by 6.3%.
Net GHG emissions reduced to 1 kg CO_2 eq/ GRFP (Lambrecht, Bonestebe, Lomelet, Le Gac, & Velghe, 2020a)

+14% on the GOS
Improved meat quantity and quality (Bechet et al., 2018)

Fattening heifers and females reduces daily work (IDELE, 2020b)

P2: Reducing and optimizing the final time between calving and slaughter

No effects identified

Net carbon footprint reduction of -1.5%(Lambrecht et al., 2020d; Schibler, 2019)

The GOS can vary from +4.1% in an optimized system to -11.7% in a long post-weaning fattening system
Gains in feed stock, straw purchase and building space (Lambrecht et al., 2020d)

Requires sorting of herd and maintenance of herd body condition, conduct varies by breed (Lambrecht et al., 2020d)

P3: Technology and precision breeding

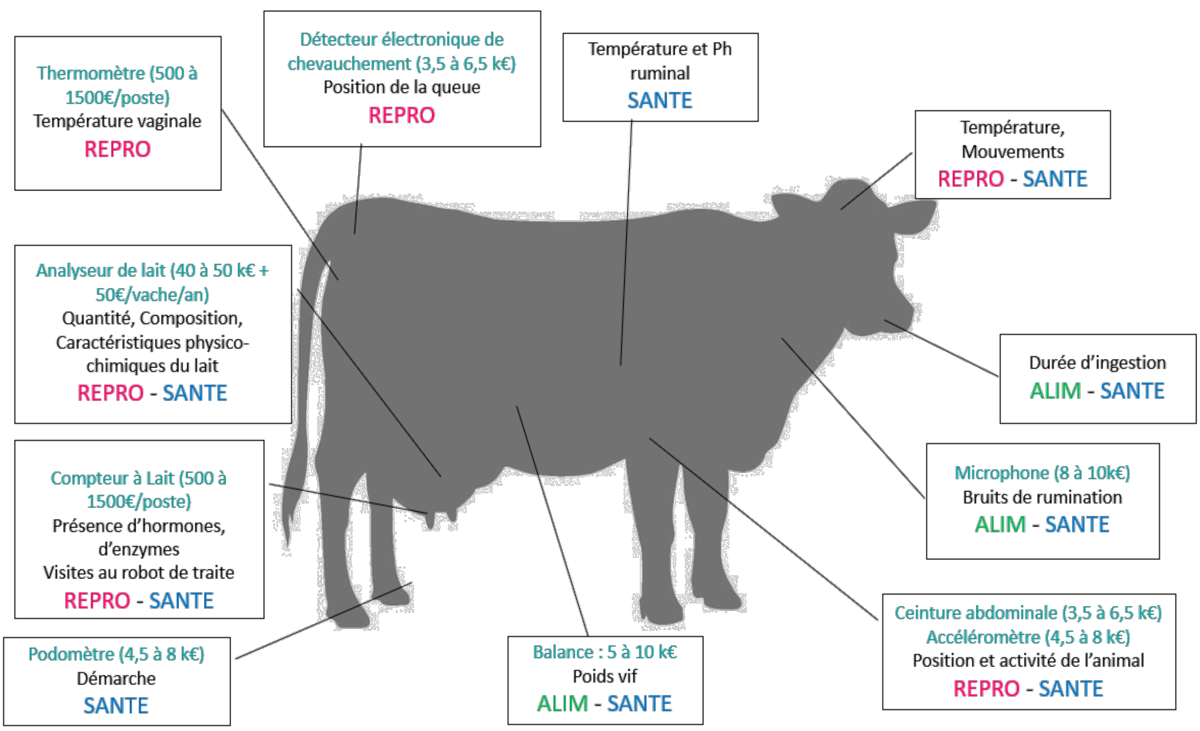
Can generate excess energy consumption, monitor water and air quality and adapt practices (Kling-Eveillard et al., 2020; Swagemakers, Garcia, Torres, Oostindie, & Groot, 2017)

Potential to reduce carbon footprint by 18-30% (Andeweg & Reisinger, 2015)

Costs vary between technologies but investments are often expensive (Figure 6)
Adapted for industrialized systems (Kling-Eveillard et al., 2020; Swagemakers et al., 2017)

Advantages and limitations vary according to the perception of the technologies and the size of the farm:
Reduction in working time adapted to large herds: work comfort
Reduces the link with the animal, which is central for some farmers
Meaning of the job: feeling of loss of capacity for some
Conflicts with other practices: example of automatic milking systems and grazing (Petit, 2017; van den Pol-van Dasselaar et al., 2020)
Modernization and taste for innovation (Observatoire des usages de l’agriculture Numérique, 2019)

Figure 6: Costs of precision technologies (Allain, Chanvallon, Clement, Guatteo, & Bareille, 2014; Assie et al., 2020; Faverdin, Allain, Guatteo, Hostiou, & Veissier, 2021; Réussir Bovins Viande, 2020)



FARM STRUCTURE

In the EU, Dairy cows are mainly housed on partially straw-covered areas, either in winter stalling systems (72%) or in buildings (60%). Suckler cows are mostly housed in free stalls with straw. Milking cows are mostly housed in side-by-side cob (61%) (Piet, 2016).

Management of natural elements

P1: Establishment and maintenance of Agroecological Infrastructure (AEI)

Maintaining the functionality of agrosystems (Bertrand I et al., 2019; Flament et al., 2013) (figure 7)

Carbon storage: Offset up to 28% of GHG emissions (Dolle et al., 2013)

→ Cultivation in grassland: 0.84 to 2.75 teqCO_2/ha/year

→ Crop in afforestation: 0,73 to 2,49 teqCO_2/ha/year

→ Grassland in afforestation: 0,1 to 0,3 teqCO_2/ha/year (Institut de l'Elevage, 2013)

Figure 7: Interest of the AEI for biodiversity (IDELE, 2018)

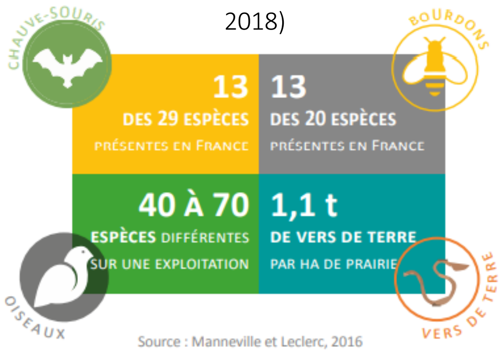


Figure 8: Carbon storage of AEIs (Institut de l'Elevage, 2013)

Variable establishment and maintenance costs (Figure 9) (Piet, 2016)

Can generate additional income or avoid certain expenses (orchards, wood) and other supports mobilized to reduce the intensity of systems (reduction of fertilizers or pesticides, establishment of winter cover) are much more expensive (Flament et al., 2013)

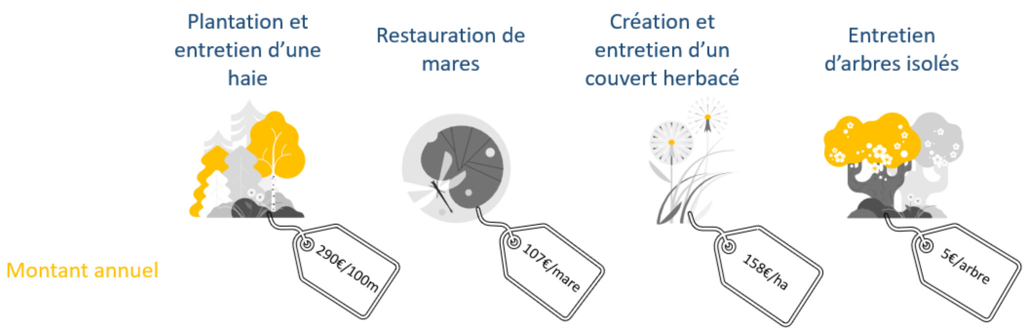


Figure 9: Annual costs of implementing the AEI for a French dairy farm (Flament et al., 2013)

Community services (landscape interests, attractiveness of the region, identity...) (Flament et al., 2013)

Livestock manure management

Effluent management contributes most to environmental and climate impacts (Castanheira, Dias, Arroja, & Amaro, 2010; Dolle et al., 2013; González-García, Castanheira, Dias, & Arroja, 2013; Guerci et al., 2013; Honan et al., 2021; Nunes et al., 2020). The strategy is to reduce the storage time, empty the pit sufficiently and limit the stagnation time to 150 days (Institut de l'élevage, 2017; Nature-Québec et al., 2011; Donal O'Brien et al., 2014). To achieve this, certain practices and investments can be made on the farm. In particular, effluents can be used as fertilizer or reinvested in energy through mechanization. The latter consists of sending the faeces (liquid or solid) as quickly as possible into a digestion reactor to promote methane production.

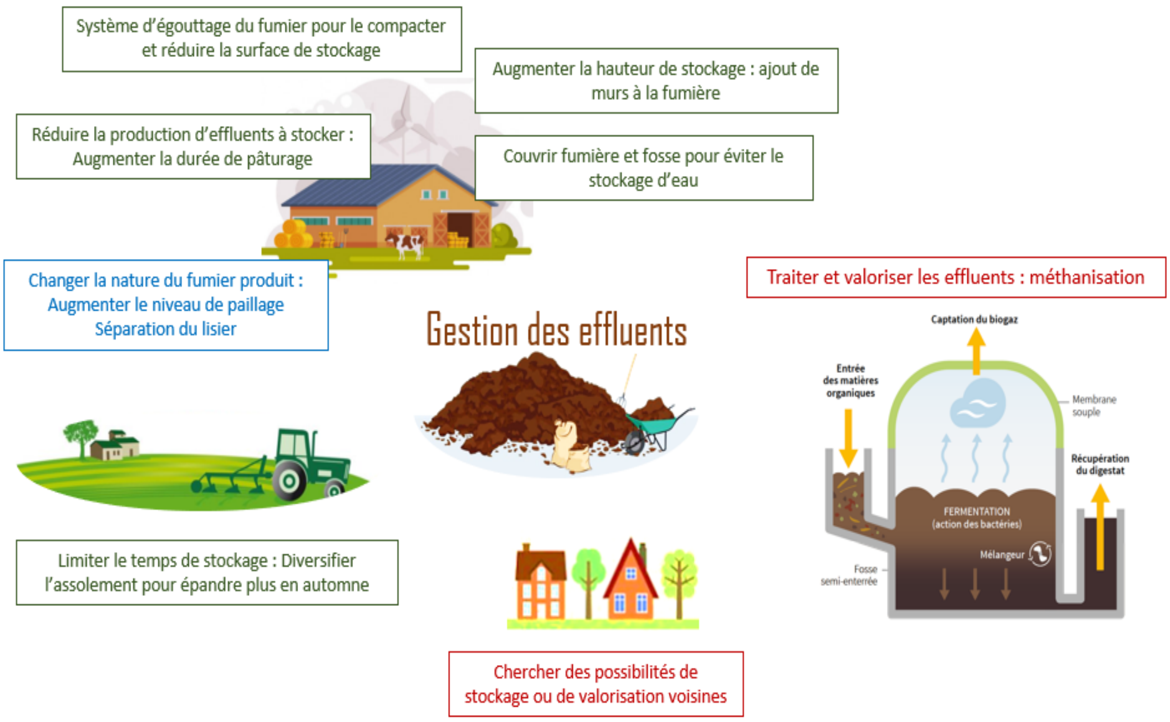


Figure 10 : On-farm manure management

P1: Reducing storage time and emptying the pit regularly via land application

Reduces the use of mineral fertilizers
Limits water contamination through leakage

Reduces CH_4 and carbon dioxide emissions from the manufacture and transport of mineral fertilizers: - 5.3 and 6.1 kg CO2/kg nitrogen (CompteCO2, 2010)

Savings on the purchase of synthetic fertilizers (around 400€/T) (Terre-net, 2021)

Spreading must be reasoned and optimized, management may require additional workload
Possibility of joint management (neighborhood) (Nature-Québec et al., 2011)

P2: Separating manure mechanically

Limits manure storage and associated air and water pollution

50% reduction in CH_4 emissions during storage (Nature-Québec et al., 2011)

Cost: €30 000 to €50 000 for an automatic separator (David, 2015)

The investment can be made for several farmers in cooperatives for the use of agricultural equipment (CUMA) (David, 2015)
Solid-liquid separation of manure concentrates phosphorus in a solid part, which facilitates its storage and spreading (Paranthoen, 2017)

P3: Covering the pit

Avoids storage and pollution of rainwater and saves space in the pit (Nature-Québec et al., 2011)

Reduction of annual NH_3 losses through volatilization by 10 to 20%. (Nature-Québec et al., 2011)

Variable costs depending on the structure

Odour reduction (Nature-Québec et al., 2011)

Table 3: Roofing costs by material (IDELE, 2020a)

type of coverage	*Costs (€/m2)*
Concrete slab	86
Inflatable roofs (waterproof)	41 – 67
Floating cover (waterproof)	47- 91

P4: Mechanization and flaring

Up to -30% on acidification and eutrophication criteria in farms engaged in methanisation (Gervais et al., 2020)

Variable effects: -3% to +14% of overall CO_2 emissions depending on the installation (Gervais et al., 2020). For 1 000 tonnes of straw bed manure, offsetting emissions of 67 teqCO2 (Lambrecht, Bonestebe, Lomelet, Le Gac, & Velghe, 2020b)

Capital invested (after grants)	*9720 €/kWé installed*
Products	98, 9 k€/year
Expenses	85, 9 k€/year
GOS	63,9 k€/year
Net margin	13,0 k€/year

Tableau 4 : Economic reference for a small-scale anaerobic digestion system of 50 KWe on a dairy herd of 140 cows in France (Gervais et al., 2020)

Participation in the local economy (Gervais et al., 2020)
Possibility of involving several farmers in a methanation unit (CUMA)
Reducing odor nuisance (neighbors) (méthaplus, 2015)

On-farm renewable energy production

The first strategy to be put in place is to reduce the amount of energy used, but the EU is also aiming for world leadership in renewable energy (Commission européenne, 2019a, 2019b; Erbach, 2016; European Commission, 2020c). However, there are significant disparities between Member States (European Commission, 2018a).

P1: Photovoltaic energy

Adds value to green energy

Carbon footprint reduction of 0.0021 kg/kWh produced (Lambrecht et al., 2020b)

Often high investment costs (Figure 11)

Cost-effective installations with high investments (industrialized structures)
Valued by society (clean and green energy)
Sense of participation in the economy of the territory (Gervais et al., 2020)

Veal calf farm		Beef farm
24 kWc	Power	200,15 kWc
158m^2	Roof surface	1 388m^2
24 369 kWh	Average annual production	227 244k Wh
30 000 kWh	Annual electricity consumption	27 000 kWh
0,8	Production/consommation ratio	8,4

Figure 11: Technical characteristics of photovoltaic installations on 2 French farms (Gervais et al., 2020)

P2: Wood energy and solar thermal

Green energy production

Producing 20 steres of wood allows the compensation of 10 tons of CO2eq (Lambrecht et al., 2020b). For a farm delivering 100 MAWC (M3 Apparent Wood Chip): compensation of emissions of 26 teqCO2 (Lambrecht et al., 2020b)

More affordable investments than PV (Figure 12)

Sense of participation in the economy of the territory (Gervais et al., 2020)

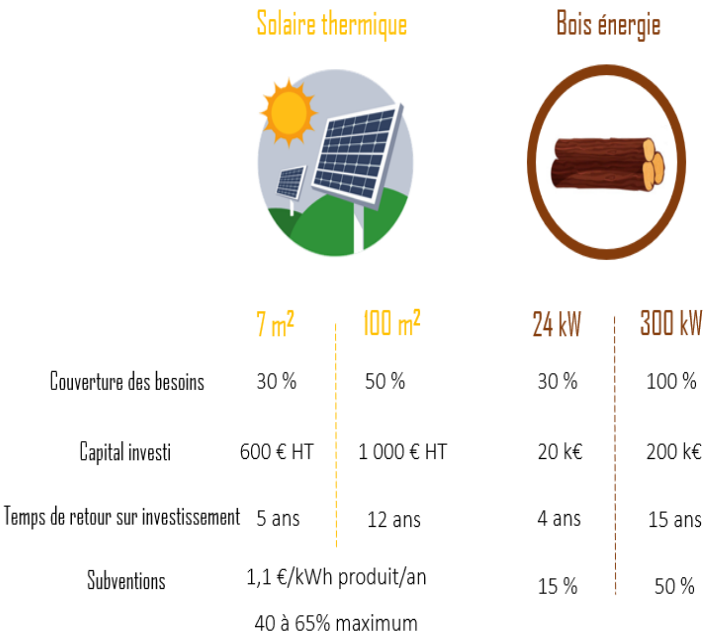


Figure 12: Economic benchmarks for a solar thermal and wood energy installation on a cattle farm in France (Gervais et al., 2020).

Brakes and levers

Livestock farms are systems operating on several interfaces, one of which is social and cultural, as described by (Donnars et al., 2019) through the concept of the barn. This interface highlights 'lock-ins' to the adoption of the livestock practices discussed in this report (Burton & Farstad, 2020a). Figure 13 presents the main barriers to the adoption of the practices of interest, as well as the levers that can be used to overcome them. The data are taken from the body of surveys studying the adoption of livestock practices (Abis & Brun, 2020; Berkes, Colding, & Folke, 2003; Burton & Farstad, 2020b, 2020a; Calvez, 2007; Chatellier & Dupraz, 2019b; Compagnone, 2019; Coty et al., 2017; d'Alteroche, 2013; Darré, 1994; Donnars et al., 2019; Ducrot et al., 2019; Dupré, Lamine, & Navarrete, 2017; Eriksson & Petitt, 2020; Guillaumin et al., 2008; Jodelet, 2003; Kebreab et al., 2001; Kling-Eveillard et al., 2020; Korea Author et al., 2009; Krstić, Derado, Naterer, & Kumalić, 2017; Lamine & Bellon, 2009; Le Blé & Morice, 2013; Liu et al., 2007; Nippert, 2018; Petit, 2017; Renault et al., 2020; Sarrazin, 2016; Sok & Fischer, 2020; Swagemakers et al., 2017; van den Pol-van Dasselaar et al., 2020).

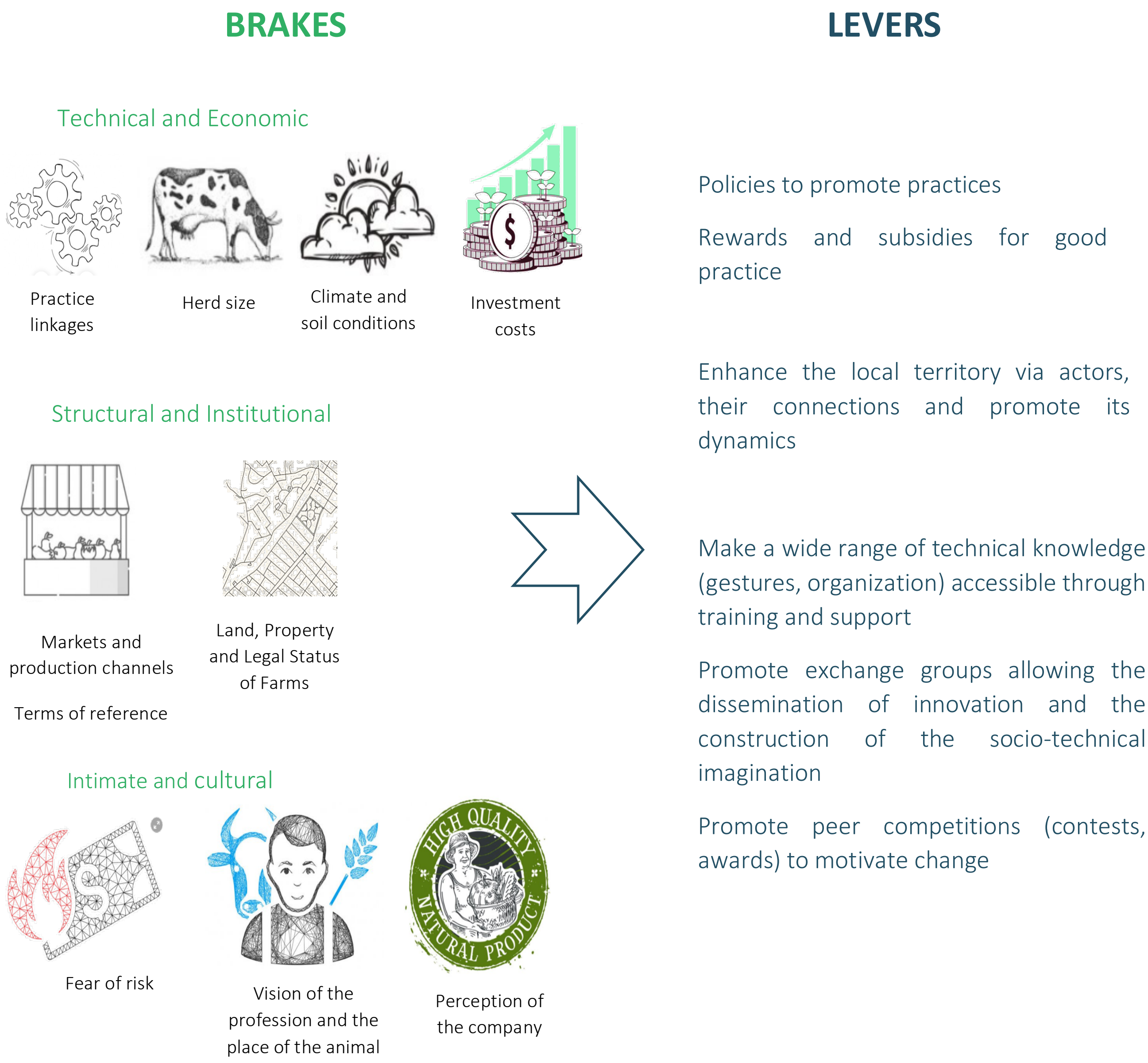


Figure 13: Barriers and levers for changing practices in cattle farming

Conclusion

The livestock practices in this report were identified from a larger set of practices based on their economic, environmental and societal feasibility for GHG reductions. To better understand their impact on the livestock system, Figure 14 shows the distribution of these practices according to their sector of impact on GHG emissions in cattle farming.

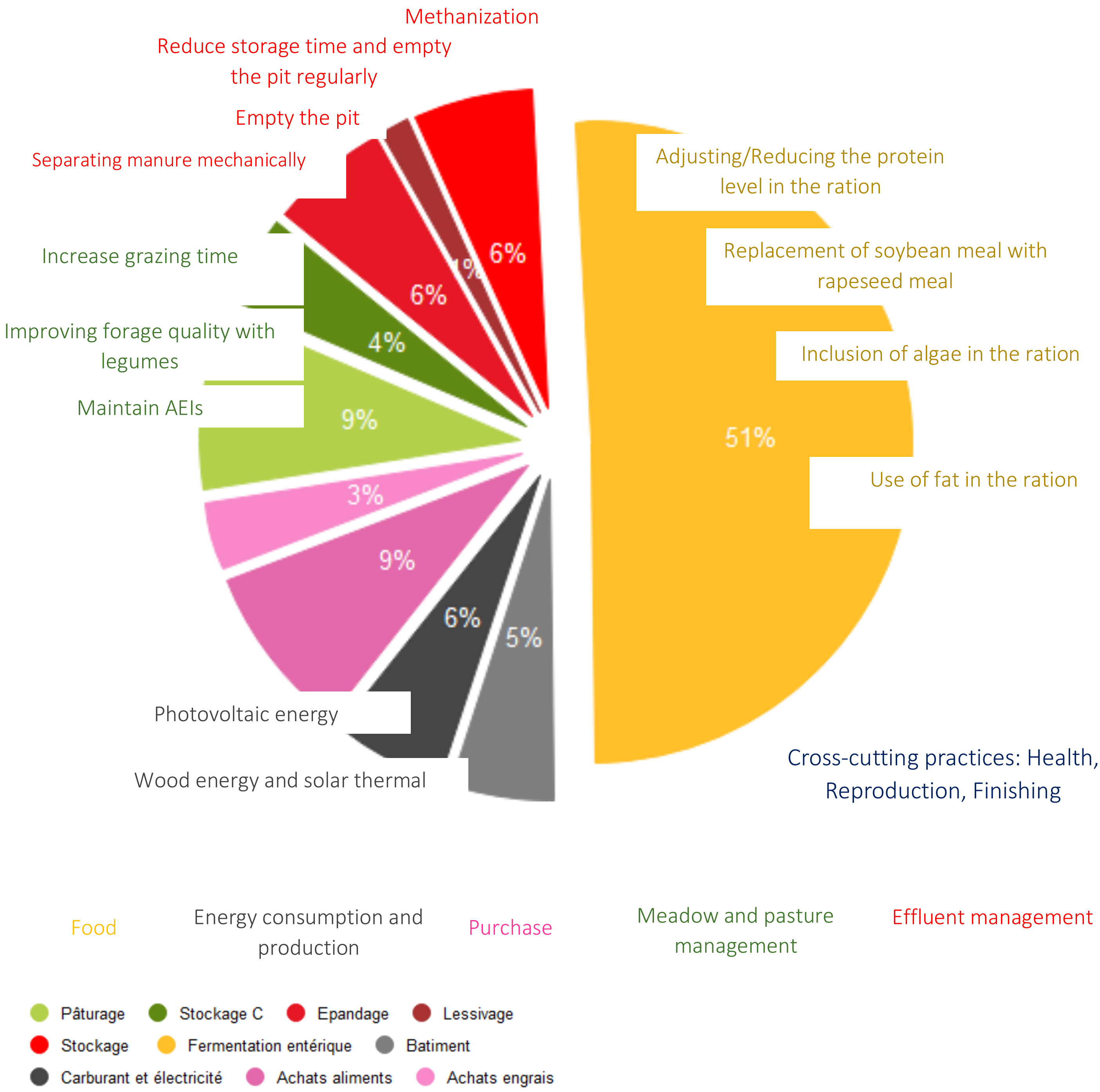


Figure 14: Distribution of practices according to their influence on the total GHG emissions of a cattle farm

This figure highlights the primary areas of action of the practices studied. It allows to classify the level of impact of the practices on the overall on-farm emissions. Practices can be cross-cutting and impact different sectors. This is notably the case for the "purchases" part, which is largely influenced by the spreading of effluents, the production of fodder, grazing or the reduction of concentrates. Based on the results obtained, it is possible to promote an efficient strategy to optimize the reduction of GHG emissions at the farm level in an economically, environmentally and socially sustainable way. It is built around 5 axes:

1. **Targeting the reduction of enteric methane emissions** which account for the largest share of on-farm emissions. The most interesting practices are **the adjustment of the concentrate rate in the ration and the replacement of soybean meal by rapeseed meal.** In addition, these two practices also limit purchases and therefore the related emissions. The inclusion of algae or lipids appears interesting but at a second stage as it may generate additional costs.

2. **Optimizing effluent management:** This is the black spot of livestock farming, both from a climatic and social point of view (odor nuisance). For this reason, **reducing storage time and good management of spreading** are the first practices to be developed on the farm. Although not very costly, they can nevertheless generate a small amount of additional work for the farmer. Methanation and manure separation are promising avenues, but require significant investment, which may prove to be a major obstacle for farmers. Financial incentives could be interesting for their development.

3. **Enhance permanent grasslands, pastures and legume-rich forages**: These strategies are key ways to reduce GHGs (carbon storage, reduction of nitrogen balance). Grasslands are also important biodiversity sites. Grazing allows the farm to become more self-sufficient and reduces the costs associated with the purchase of concentrates. However, land tenure, apprehension and lack of knowledge about the practice can be obstacles to their application. The development of exchange groups can help to overcome these issues.

4. **On-farm energy production** is an area for improvement and should be reserved for certain farms. Although promising, it can be very costly and requires a commitment from the farmer to these issues. The establishment of this type of structure requires financial and educational support to ensure its success.

5. Finally, in terms of herd management, it is important to ensure that the herd is in **good health** in order to limit the costs and environmental impact of the use of medicines, particularly antibiotics. Also, **reducing the number of unproductive animals by lowering the age at first calving or by reducing the renewal rate** is an economically and ecologically interesting strategy. Similarly, **increasing the finishing rate and optimizing the time between calving and slaughter** can increase the productivity of the farm in a rational way and reduce costs and negative climatic and environmental impacts. **Genetic selection and precision breeding** are also interesting practices, but at a later stage. These practices may conflict with the representation of the breeder's profession and with other practices implemented on the farm.