# Energy and carbon footprint of food in France

## *from production to consumption*


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# Overview

This booklet is a product of the CECAM project (Contenu énergétique et carbone de l'alimentation des ménages – Energy and carbon content of household food consumption), managed by the Club d'Ingénierie Prospective Énergie et Environnement.

The perspective chosen is that of the household food consumption in mainland France, in contrast with the food production and processing of the French territory. The results presented consider the main energy consumption and greenhouse gas emissions of the average diet of the French population, taking into account the consumption and emissions contained in the imports of intermediate or final products, and excluding exported French production. This study details the relative contributions to the total footprint derived from the main stages of the food system: agricultural production, processing, freight transport, distribution, out-of-home eating, travel for household food purchases, and food preparation in the home.

We brought together data from statistics and models of agricultural production, food consumption, processing and transport. Ultimately, the aim would be to use the assessment and simulation tools developed for a foresight exercise. Indeed, the combination of the models used will enable the simulation of changes in the various stages of the food system (production methods, processing, possible relocation to France of imported products, transport reductions throughout the sector, supply modes, and dietary change) and to assess their impact on energy consumption and greenhouse gas emissions.

**The Project Steering Committee included Michel COLOMBIER (IDDRI), Sarah MARTIN and Laurent MEUNIER (ADEME), Isabelle PION (MAA), Olivier DE GUIBERT and Elisabeth PAGNAC-FARBIAZ (MTES), Pierre CLAQUIN and Julien HARDELIN (CEP-MAA), Arthur RIEDACKER.**
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CONTENTS

# Food is at the intersection of social, health, economic and environmental issues

The issue of food is crucial because it is the most essential commodity, its study is highly complex, and its impacts are both diverse and large scale. In the current context, food is once again becoming a major public issue with consequences for social, local, and ecosystem and economic balances, both at the local and global scales. While the situation for France is addressed here, the ability to meet food requirements while respecting the limits of our ecosystem is a key issue on the global scale, with highly interactive dynamics.

The issue of food is a perfect example of a "cross-functional" subject that cannot be addressed in isolation from other sectors of society: "we eat the way we live". Whether taking a sectoral approach (health, water, biodiversity, climate, soil, resources, lifestyle, local jobs, costs, etc.) or a geographical one (a drought in Russia or food riots in the Maghreb can have an impact here), the large number of interdependencies means that, in a situation of multiple constraints, it is no longer possible to take a silo-based approach to the issue, as is frequently the case. For example, limiting the use of fossil fuels leads to increased mobilization of biomass for non-food uses (materials, energy, etc.) and therefore to land use competition; or the fragmentation of value chains or strong growth in trade affect all economic sectors and reconfigure food chains. Thus, work that contributes to a better understanding and modelling of the functioning of food systems and interactions with the rest of the economy is essential.

### *Multiple determinants*

Food demand is changing to address social, nutritional, health and environmental concerns. The determinants of these developments are therefore multiple.

The food system is shaped by different types of public policies at both the national level (French National Nutrition and Health Programme, Common Agricultural Policy, National Low Carbon Strategy, etc.) and the regional level (Territorial Food Plan, Regional Biomass Scheme, etc.). The development strategies of commercial actors also influence food demand, whether through advertising or the supply format.

There is a growing demand for the assessment of the environmental impact of food. Given that food is the cause of a significant proportion of greenhouse gas emissions, as we will see, it is one of the targets of policies to address climate change. Environmental labelling of products and longer-term strategies to reduce GHG emissions are intended to encourage changes in household diets and eating habits, and beyond this, to impact on the methods and locations of agricultural production. A long-term vision of food demand is needed for any national or regional planning exercise.

### *Tools for simulation and decision-making support*

Given the scale of the limitations to which we must adhere, production and consumption modes must change radically and rapidly to contain the risks of systemic imbalance, whether in terms of health, global warming, biodiversity loss etc. Changing our diets and eating habits has become an act of citizenship, making changes at our own level to affect the organization of the food system, to create social bonds, or to change our relationship with nature.

All of these concerns require a rethinking of our food system: the nature of agricultural production and its location, the methods of processing, the associated demand for transport, etc., but also the importance of the agricultural area dedicated to food in future, and the possible land-use changes towards non-food crops.

To assess the environmental impact of these developments, a global approach to production, processing and consumption systems is necessary, both to grasp their interdependencies and to consider their futures. The simulation tools developed are intended to inform the decisions of public and private actors. The work presented here is part of this perspective. The first part of this document is devoted to the methodology and tools developed for carbon footprint assessment. The results are then presented by following the different stages of the food system, from the farm production stage to the final consumption of households.

# Main methodological elements

It is necessary to adopt a systemic approach, along with assessment by performance indicators, to anticipate the evolution of food demand while taking into account the evolution of demographic structures and social standards, to make choices in production systems, to valorize resources by suitable processing means, and more generally to favour regional selling opportunities. This systemic approach ensures coherence with national, macroscopic and individual sectoral statistical data collected throughout the food chain.

## *Adopting a global approach to the food system*

In the French and international literature, the Life Cycle Assessment (LCA) approach is dominant and provides global GHG emissions for a range of food products (Perignon et al., 2016). Thus, ADEME's AGRIBALYSE programme, provides a consistent and transparent database for assessing the environmental footprint of agricultural products. In addition to this LCA approach and sometimes in a mixed way, a global approach is relevant in foresight exercises, especially to take into account changes at different stages of the food system.

The systemic approach proposed here is innovative in three ways:

a) It is based on a process of disaggregation and allocation of food volumes and environmental impacts at different stages of the production chain. It begins with the diet that determines the demand for agricultural and food products, and then reconstructs the upstream phases of the production and distribution sectors. It is verified by the coherence established with the national sectoral and energy statistics at the various links.

b) It assesses the national, European or global origin of all food products using a transport flow analysis model.

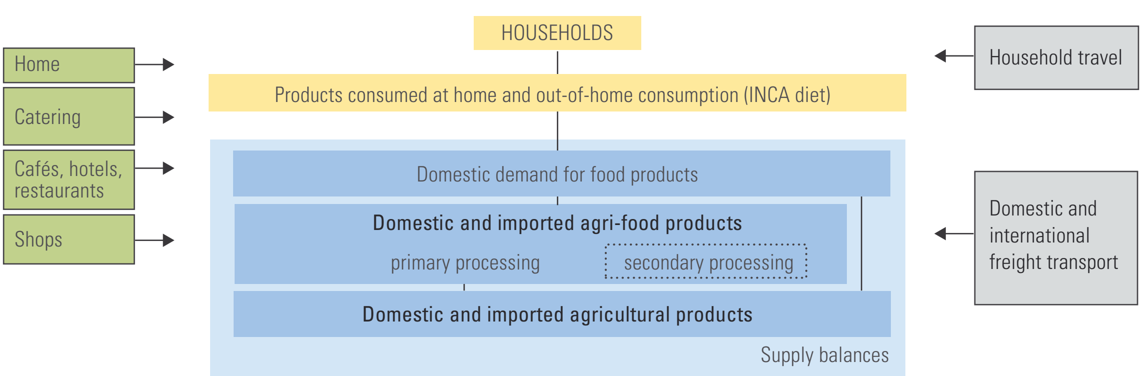
c) It enables the varying of parameters, at the level of agricultural production systems, land allocation decisions, processing, transport demand according to modes, level and the origin of imports, technological progress and losses along processing chains. These parameters make it possible to take prospective changes in the food system into account, in relation to changing diets (average or by population category) and to assess the corresponding environmental impact.

In this summary we present the material flows, energy consumption and greenhouse gas emissions of the main components of the food system that have been used in CECAM. The scope is shown in **Figure 1**, which includes the production, processing, distribution and consumption of food at home and out-of-home, as well as most of the freight transport and household trips for food shopping or to eat out of home. Freight transport, based on the SITRAM study, takes vehicles over 3.5t into account, and therefore transport provided by light-duty vehicles of less than 3.5t is not incorporated at this stage of the analysis. Packaging and waste are also not taken into account. Finally, the analysis focuses on food consumption of the population of mainland France. Therefore, French overseas territories are considered as external and grouped in a specific region.

## *Tracing material flows along the food chain*

Supply balances by product type were developed to enable material flows throughout the chain to be detailed, and to integrate imports and exports. This is a physical approach

**Figure 1.** Scope of food system considered in CECAM




*Source: Authors*

that matches material flows from the production stage to the final consumption of households, and includes processing, transport and distribution. This method was preferred over a monetary value approach as it ensures a more robust match between all sectors.

Supply balances are broken down between resources on the one hand, and uses on the other, the two terms being in equilibrium. Resources consist of production and imports, and uses consist of domestic uses (for further processing or for final consumption) and exports. Different supply balances can be combined with others to design flow diagrams. It should be noted that for the entire document, the terms *imports* and *exports* refer to France's international trade.

The flow diagrams are Sankey diagrams that enable the visualization of the different flows from primary production and imports, towards final uses, via the different stages of processing, and thus provide a better understanding of the overall functioning of a sector.

Diagram visualization also enables the completion of the supply balances downstream of each sector. Indeed, AGRESTE or FAO data usually stop at primary (raw milk, rapeseed) and secondary (cheese, rapeseed oil, rapeseed cake, pork carcass) production, and do not consider tertiary production (processed meat, prepared meals, bakery products), and there is often a significant gap between the diet as described by food consumption surveys (such as the INCA survey) and supply balances.

Flow diagrams are not developed in primary equivalent but in real physical flows. Thus FAO's supply balances are supplemented by an additional section, "final consumption", which corresponds to the notion of "food availability", but is corrected by a factor that takes physical flows into account. Thus, beef consumption is estimated at 1.6 Mt in carcass weight equivalent, but 1.1 Mt in meat. For fruits and vegetables, it is also possible to convert "food supply" data by fine-tuning with these coefficients. This is particularly necessary, for example, for fruits and vegetables that have been processed into concentrates for juices, because the difference in volume can be highly significant in such cases. These physical flows are then used for the assessment of the transported flows, which can be compared to the food consumed. **Figure 2** is an example of a flow diagram for the pig industry, which at each stage shows losses in mass, along with imports and exports.

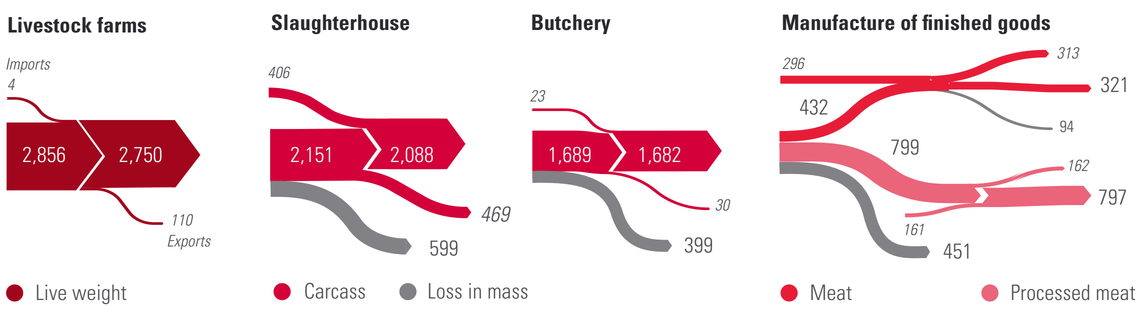
## DATA SOURCES

Data from numerous national and international statistical surveys have been used to assess material flows, energy consumption and greenhouse gas emissions. The main sources are those of FAO, AGRESTE, INSEE, the Prodcom and Eurostat surveys for agri-food production and international trade; the SITRAM and ENTD surveys of the French Ministry of Transport for transport; and the ANSES INCA2 survey for diets.

### *From purchased products to food consumed*

In flow diagrams, each step considers a loss rate. Similarly, at the end of the chain, to link food ingested, provided by food consumption surveys, to products acquired by households and to supply balances, it is necessary to take into account the mass variations due to cooking (mass loss or increase in the case of rice or coffee, for example), to processing (bones, peels, shells), to consumption losses, etc. This also requires going back to the ingredients used, for example a savoury cracker is composed of different flours, water, oils, yeast, salt, etc. To go from the weight of ingested food to the weight of the ingredients, two main factors are taken into account: the edible part of the ingredient (not including shells, peels, kernels, bones) and the addition or loss of water (cooking, drying, concentrating). A loss rate is thus evaluated, including wastage before and after culinary preparation.

**Figure 2.** Flow diagram example, the pig industry (thousand tonnes)




Source: Authors

### *Calculation of carbon footprint*

The aim is to evaluate the energy consumption and greenhouse gas emissions generated by our food at all stages "from farm to fork", whether on mainland France or contained in imports. Energy consumption and GHG emissions for the production of exported products are excluded. We present here the method used and the scope considered.

#### *Greenhouse gas (GHG) emissions from agriculture*

GHG emissions from agriculture in mainland France are estimated using ADEME's CLIMAGRI method. The analysis is based on the use of real statistical data, and consumption or emission coefficients (for example, ammonia volatilization rate, weight of nitrogen applied, methane emission rate per animal as a function of its food ration). CLIMAGRI uses a functional accounting format, which can be compared to the sectoral accounting format of the United Nations Framework for Climate Change (UNFCCC): it includes "agriculture" items (category 3), but also other items accounted for in the "energy" or "industry" sectors.

Direct emissions are those emitted by farms: the main gases are methane generated by enteric fermentation and livestock waste, and nitrous oxide, which is essentially related to the nitrogen cycle in the agrosystem (nitrogen volatilization or leaching from fertilizers and livestock waste, ammonia emissions from livestock farming). Carbon dioxide derives from fossil fuel combustion (mainly fuel for tractors and greenhouse heating) and soil improvers such as lime. Indirect emissions are related to the supply of agricultural inputs, such as the manufacture of nitrogen fertilizers and plant protection products, equipment manufacture and farm building construction, and to emissions from the energy sector induced by final consumption of agriculture (such as refineries, etc.).

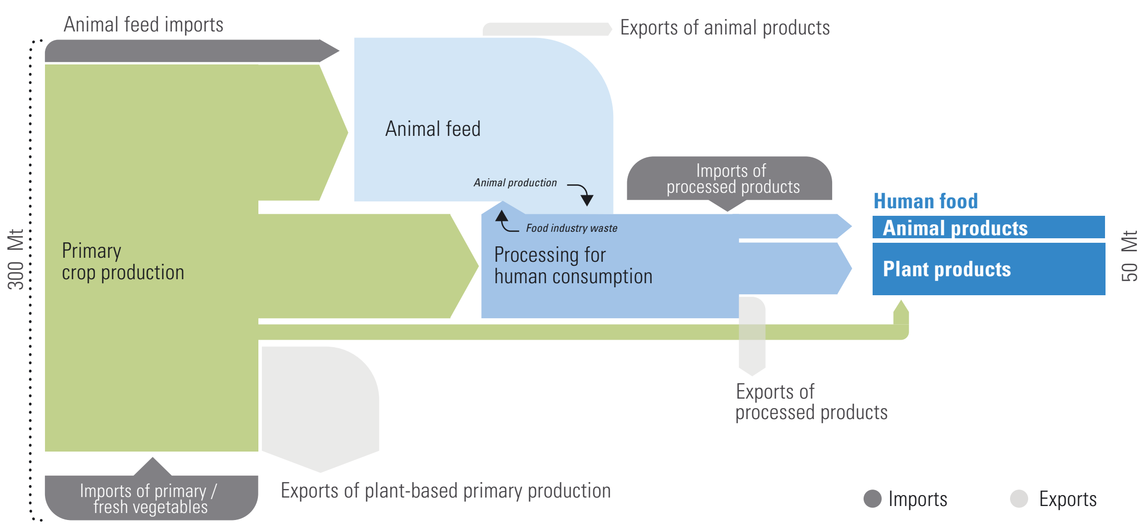
In addition, methane emissions are accounted for using the Global Warming Potential (GWP) over 100 years, which underestimates the impact in the shorter term.

The analysis does not include LULUCF (land use, land-use change, and forestry) as this would require a more comprehensive approach to land use. This limitation mainly affects imports and exports, for example by underestimating the carbon footprint of agricultural production related to deforestation.

#### *Taking imports and exports into account*

To this scope defined in CLIMAGRI, we add the emissions of imported food products, while the emissions of exported products are subtracted using flow diagrams. Imports and exports of agricultural products are accounted for

**Figure 3.** Importance of material flows from crop production to the plate




Description: This figure provides a simplified overview of the masses of plant products mobilized for human consumption, the share that is consumed by livestock, the share transformed for our plant-based food, and that which is consumed directly. About 300 Mt of crops is produced in France or imported per year (left side of figure), of which about 70 Mt is exported (cereals, milk, etc.), and 110 Mt is for animal feed. At the end of the chain, about 50 Mt of food is consumed by the population of mainland France, including 15 Mt of animal products and 35 Mt of plant products.

*Source: from FAO, Agreste, Eurostat, INCA2 survey* by allocating them with a “carbon content” derived from databases used in the production of LCAs for example (AGRIBALYSE, EcoInvent, etc.). It should be noted that international data for these LCA are sometimes missing. Further research would be required to consolidate these data, and also take into account land use changes where appropriate.

#### *Emissions from non-agricultural sectors*

For sectors other than agricultural production, we considered direct energy consumption and $CO_2$ emissions, as well as HFC emissions from refrigeration in the tertiary, residential and refrigerated transport sectors.

The results we obtained can therefore be regarded as low estimations, which could be revised upwards by expanding the scope of activities, and by considering the indirect energy consumption of non-agricultural sectors, and all greenhouse gases at all levels. A more comprehensive assessment would not, however, change the hierarchy of the environmental impacts presented.

### *Limitations of the statistical tools*

This exercise requires the use of numerous sectoral surveys that use nomenclatures that are insufficiently coordinated, and databases that are relatively precise and should encompass all countries. It is rare that standardized data are available for agricultural products and processed products, in terms of the level of detail and the geographical area. In addition, there are no public surveys that include all marketed products, which would provide reliable data to construct supply balances and the interfaces with food consumed.

Nevertheless, while there remains room for some data to be consolidated, we have been able to build a coherent set of assessments of the carbon impact of the food system, which addresses in a relatively detailed way the demand for national and international transport, and is relevant for conducting foresight exercises.

### MOBILIZED MODELS AND INTERFACES

The carbon balance assessment tool is composed of different models that are linked to each other by interfaces. Certain tools can or cannot be mobilized, depending on the desired scope of evaluation.

- The MoSUT model, developed by SOLAGRO, provides a description of land use for the entire territory and of French agricultural production, evaluating the environmental footprint of the “France Farm”.
- The AMSTRAM model, developed by FIRE-CNRS, processes information from the SITRAM database (Ministry of Transport) for freight transport and describes the interdepartmental and international transport flows. The methodology used enables the evaluation of the total distances travelled, including intermediate loading/unloading, as well as trips within the country of origin. Thus, for Brazilian soybean meal, this includes the trip by road in Brazil to the port, sea transport to France, and then the trip from the French port to the destination department (see **Figure 13**). Transport ratios are evaluated in t.km/tonne of finished products placed on the market.
- The IMMOVE (Integrated Model of Mobility, Vehicles and Energy) model developed by EDF provides a representation of households and all their movements, local and long distance, as well as the vehicles they use. Here, the analysis deals with trips for food shopping and visits to cafes/restaurants.

Transition matrices have been established between INCA2 nomenclature, FAO agricultural commodity nomenclature, the NAF rev2 for agri-food products, and the Standard goods classification for transport statistics (NST). They divide the food demand into 43 classes of agricultural and agri-food products, which in this document are grouped into 16 major categories, representing the annual domestic demand for food products.

# Food consumption

**KEY FIGURES**

- **An individual in France consumes approximately 2.4 kg of food daily, half solid food and half drinks.**
- **Two-thirds of this solid food is of plant origin (cereal products, fruits and vegetables) and one-third is animal products (mainly milk and meat) (Figure 4).**
- **For fruits and vegetables, the imported proportion exceeds 40% for certain products such as tomatoes, cucumbers, peaches/nectarines and grapes (excluding citrus fruits and bananas, which are not produced in mainland France). This represents one of the main food transport items, just below animal feed.**

Our diet is constantly evolving although it is strongly determined by culinary habits. A survey conducted in four European mid-sized cities shows that food is the area for which households are more ready to take action to reduce their carbon footprint, ahead of housing and mobility (Sköld *et al,* 2018).

Daily consumption of drinks (1,268 g/day/person) is dominated by drinking water, half of which is bottled water. The INCA2 survey does not reveal the extent to which hot drinks were made from bottled or non-bottled liquids. Nevertheless, we can consider that more than half of the drinks consumed are bottled. This means that the French mainland population consumes 15 million tonnes of bottled drinks per year (water, soda, wine, beer, etc.). To this we can add 2.3 Mt of milk (included in dairy products) and 1 Mt of fruit juice (included in prepared fruits). These drinks, even if they are produced mainly on the territory, will still generate significant transport and encourage shopping trips by car.

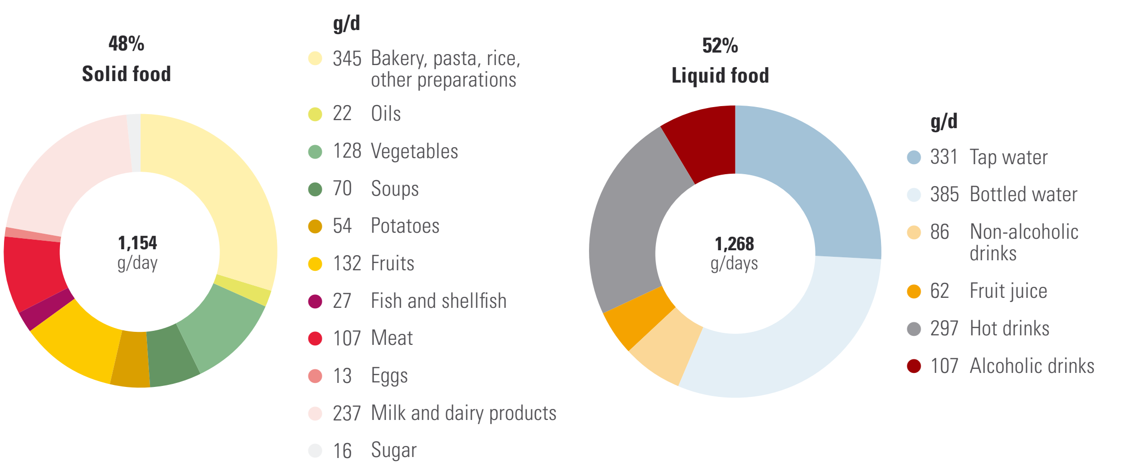
## *Dietary diversity*

Diets vary greatly according to individuals and population types. The national survey on food consumption (INCA 2) conducted by ANSES, provides information on diets according to the socio-demographic characteristics of households (age, gender, income level, educational level, location). This differentiation is relevant for the design of scenarios for alternative futures according to population groups.

If we take the example of meat consumption, we can see a great divergence among the population. In **Figure 5**, we differentiated the adult population according to deciles of meat consumption, in quantities consumed per person per day. Meat consumption is only 26 g/d for the lowest 10%, but reaches up to 234 g/d for the highest 10%. Gender is a highly discriminating factor in relation to diet. This is certainly the case for meat consumption, with women accounting for 86% of the lowest decile, and 28% of the highest decile.

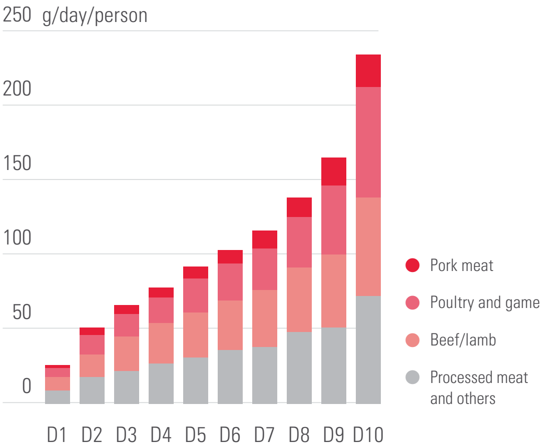
Other groups that consume the lowest amounts of meat are low-income, young and elderly people. In low meat consumption deciles, this level of meat consumption is compensated for by mixed dishes, soups and fish.

**Figure 4.** Composition of the individual diet in France




*Source: INCA2, for the year 2008*

**Figure 5.** Heterogeneity of meat consumption




*Source: INCA2*

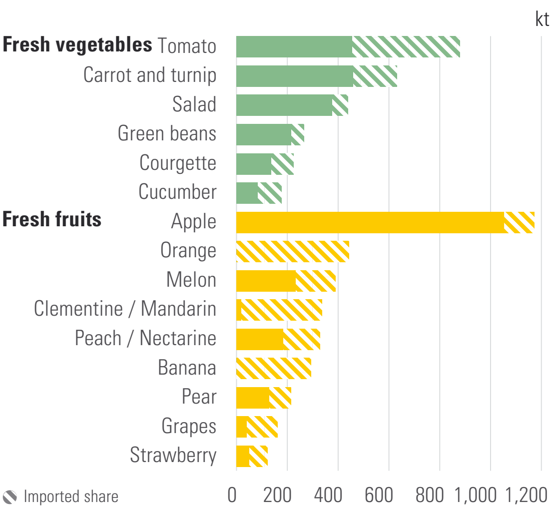
The 2017 INCA3 study also indicates that food is increasingly consumed in processed forms: vegetables, cereals, meat and fish. The consumption of sandwiches, pizzas and other savoury baked products has also increased since the INCA2 survey. In contrast, the consumption of legumes is stable, and remains marginal at less than 10 g per day.

## *Long distance out of season foods*

Fruits and vegetables, along with fish and shellfish are the products with the highest proportion of imports, whether fresh, frozen or processed. If we take the vegetables and fruits most consumed according to the INCA2 survey (**Figure 6**), the imported proportion of marketed volumes (all uses) reaches 40 to 50% for some vegetables (tomatoes, cucumbers, courgettes). Apples are mainly produced in France, but this is far from the case for other fruits. Of course, citrus fruits and bananas are not produced in mainland France. For the other five most consumed fruits, imports account for between 39% (pears) and 74% (grapes) of the volumes traded in France. **Figure 6** shows the volumes of fresh vegetables (all uses) imported per month. Imports are an addition to the seasonal production in mainland France, with products coming from Spain in May/June, and earlier in the year from Morocco and other countries in the winter. These imports therefore ensure a consumption of vegetables outside of the French production season. A similar phenomenon occurs for fruits. Nearly half of fruit imported comes from Spain, the Canary Islands, Balearic Islands and Italy; while the rest comes from very diverse areas, which are often remote (Africa, Latin America). The import peak occurs in December with 300 kt of fresh fruit imported.

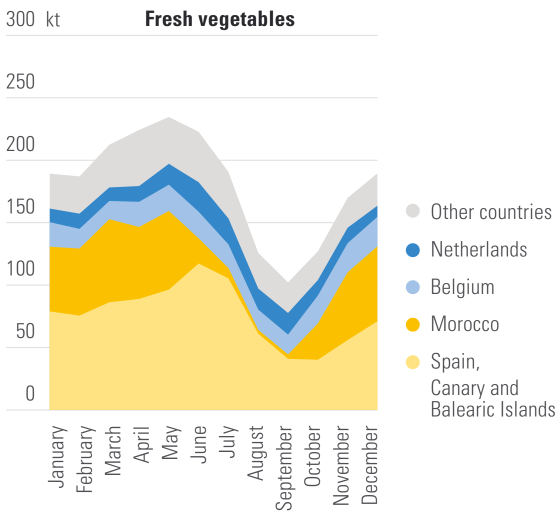
**Figure 6.** Fresh fruit and vegetable imports and seasonality

*Marketed volumes of the most consumed products*




*Source: CTIFL, INCA2*

*Import volumes per month and country of origin*




*Source: CTIFL, for the year 2015*

# Agricultural production and processing for domestic consumption

**KEY FIGURES**

- **The land area required to feed the French population (26 Mha) is slightly lower than its agricultural area (28 Mha).**
- **Meat and milk consumption utilizes more than 80% of the agricultural area.**
- **Half of the agricultural energy consumption is indirect energy (related to inputs and equipment).**
- **The carbon content of exported agricultural products exceeds the carbon content of imported products by 9 $MtCO_2Eq.$, which is about 8% of the GHG emissions from French agriculture.**
- **With the exception of fruit, vegetables and fresh seafood, most products consumed have undergone one or more processing steps. Energy consumption from processing is of the same order of magnitude (4.9 Mtoe) as the energy consumption of agricultural production stage. However, processing-related $CO_2$ emissions (9.1 $MtCO_2$) are 10 times lower, due in particular to the significance of $CH_4$ and $N_2O$ emissions from agriculture.**

Mainland France has a land area of nearly 55 million hectares, which consists of 51% agricultural land; 30% forest; 10% uncultivated land, moorlands and others; and 9% built-up land. The utilized agricultural area (UAA) in mainland France is 28 million hectares, a figure that has decreased by 6 Mha since the 1960s, mainly due to an increase in forest areas and land artificialization.

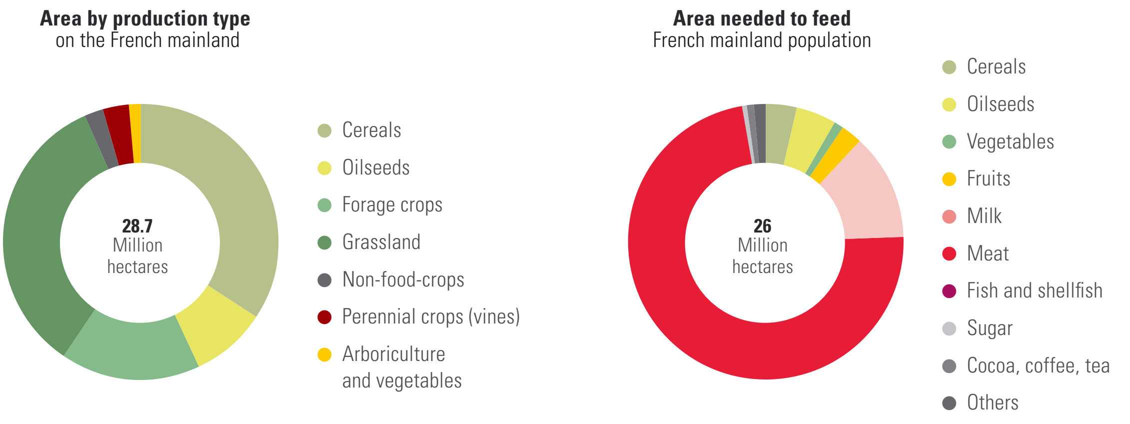
## *Agricultural area is strongly mobilized for livestock farming*

A large proportion of the agricultural area in France is used for livestock farming. Pastures and fodder crops account for half of the agricultural area, on top of which are areas under cereals for animal feed.

A closer examination of the dietary footprint in terms of agricultural area, i.e. the agricultural area in mainland France excluding exports and areas used for imported products, reveals that the consumption of meat and milk mobilizes more than 80% of the agricultural area needed for the entire French diet (**Figure 7**). This of course includes all pastures and fodder crops, but also the majority of the area dedicated to cereals (barley, grain maize, oats, wheat, etc.), co-products and by-products of the oilseed sectors (meal) and of certain industrial sectors (cereal bran, beet pulp), to which we must add the production of imported soybean meal. This figure can be considered in relation to our diet, which is only one-third composed of animal products (in quantities consumed, see **Figure 4**).

Logically, the GHG footprint of animal products reflects this situation. When we include methane emissions from enteric fermentation, livestock waste, and

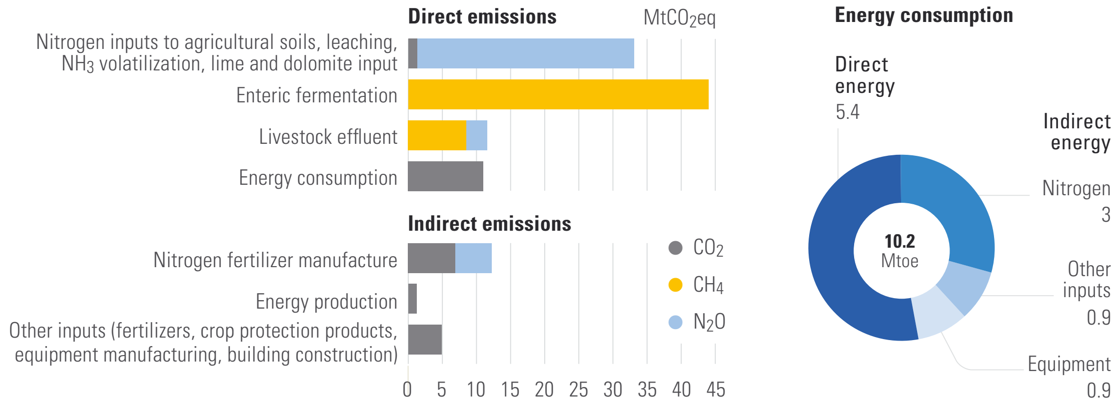
**Figure 7.** Allocation of agricultural area




*Source: Agreste*

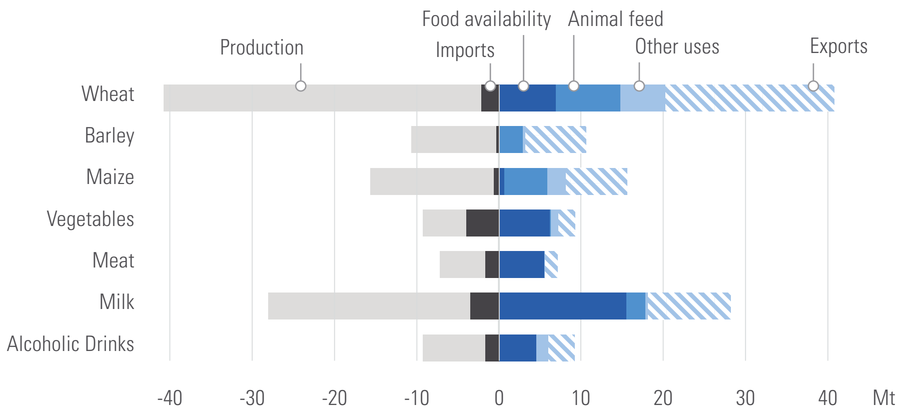
*Source: Authors. The areas are evaluated from the production system yields per hectare*

**Figure 8.** Territorial GHG emissions and energy consumption of agriculture (2008-2013 average)




*Source: CLIMAGRI*

**Figure 9.** Resource-use balance of selected agricultural products




*Source: FAO*

nitrous oxide emissions from fodder crops, meat and dairy products account for 85% of the GHG footprint of our food, in relation to agricultural production.

## Methane and nitrous oxide are the dominant emissions from the agricultural sector

Agriculture in mainland France emits 118 $MtCO_2eq$. of which 84% is direct emissions (**Figure 8**). Methane, mainly from livestock farming (enteric fermentation and effluent), accounts for 44% of the total, and nitrous oxide (nitrogen fertilizers) for 34%. The direct energy use of farms, and the indirect input-related energy use, results in emissions of 25 $MtCO_2$, i.e. 21% of the sector's total. These total emissions are slightly decreasing: direct emissions fell by 5% between 1990 and 2015, in correlation with a decrease in the cattle herd and in the use of nitrogen fertilizers.

## Balanced foreign trade in agricultural products

To calculate the footprint of the French diet, it is necessary to add the GHG emissions content derived from imported agricultural goods, and to symmetrically deduct that of exported commodities. For this purpose we use supply balances, which show the resource-use balance of each type of agricultural production (**Figure 9**). Resources consist of domestic production and imports, while uses include the utilization for human food, animal feed, and other uses such as seeds and exports.

France is a net exporter in tonnes of agricultural products: it exports half of the cereals produced and one-third of its milk (**Table 1**). Conversely, France imports large quantities of fruits, vegetables, fish, soybean meal, and meat. Foreign trade generates a positive balance of GHG emissions at the agricultural production stage for France, i.e. the carbon content of exported products exceeds the

**Table 1.** Import/export balance and GHGs

| Main items | Balance exp./imp., kt | GHG balance, $ktCO_2eq$ |
|---|---|---|
| Cereals | 27,100 | 9,710 |
| Milk | 7,086 | 7,370 |
| Oil plants | 1,050 | 968 |
| Poultry meat | 202 | 509 |
| Pig meat | 90 | 318 |
| Legumes | -132 | 298 |
| Alcoholic drinks | 1,380 | 221 |
| Animal fat | 477 | 198 |
| Potatoes | 1,590 | 113 |
| Sugar | 1,950 | 72 |
| Eggs | - 22 | -38 |
| Stimulants | - 670 | - 109 |
| Oils | - 317 | - 226 |
| Bovine meat | - 46 | - 714 |
| Fruits | - 5,540 | - 904 |
| Vegetables | - 1,800 | - 994 |
| Fish and shellfish | - 1,670 | - 2,290 |
| Meal and bran | - 3,340 | - 2,530 |
| Sheep/goat meat | - 98 | - 2,720 |
| TOTAL | | 9,252 |

*Source: Eurostat, Solagro*

carbon content of imported products. The export balance is 9.3 $MtCO_2eq$. Agricultural GHG emissions related to the domestic food demand of France therefore amount to 109 $MtCO_2eq$ (territorial emissions of agriculture , 118 $MtCO_2$, minus the export balance).

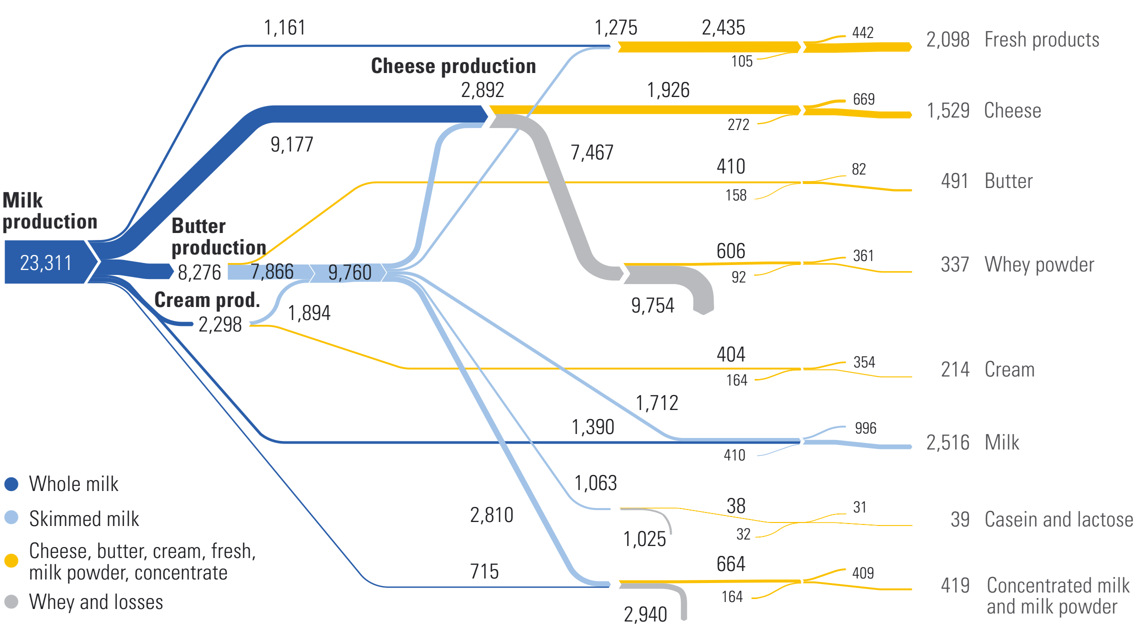
## *Energy consumption is divided between fuel consumption and input production*

CLIMAGRI also enables the estimation of the energy consumption of agriculture in mainland France: out of 119 TWh of final energy consumption, 53% is linked to direct consumption, which is mainly fuel, and 47% to indirect consumption, mainly the production of nitrogen fertilizer. Indirect consumption does not distinguish between mainland France and imports: today, more than half of nitrogen fertilizers are imported. To consider this in terms of footprint, the energy consumption of agriculture related to domestic demand is estimated to be 10.2 Mtoe (**Figure 8**).

## *The processing industry supplies most of the food consumed*

The raw agricultural products consumed by households are mainly fresh fruits and vegetables, and fresh fishery products. As a result, most of the products we consume have undergone one or more processing phases. Over the 2012-2014 period, food production by agri-food industries in France averaged 124 Mt per year. Note that this figure does not only include the production of finished products, since some of these products are used as intermediate inputs by secondary processing industries. Material flows are complex within this sector and can only be visualized

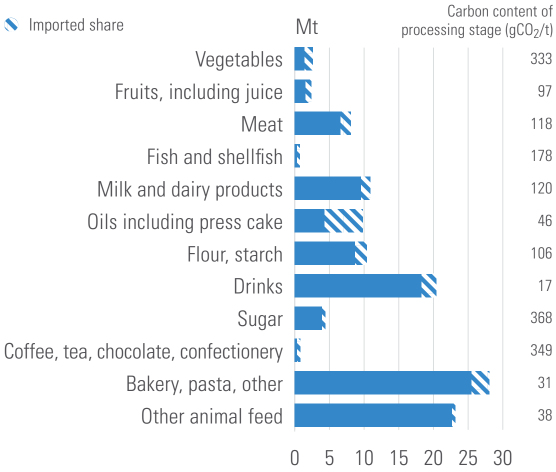
**Figure 10.** Supply balance of milk and dairy products




*The bulk of milk production is directed towards dairies or cheese factories, which process whole milk into different products (fresh products such as yogurts, cheese, cream or butter) or generate skimmed milk for final consumption. The manufacture of cheese leads to the production of a co-product, whey, which can in turn be consumed by animals, or more generally be transformed into whey powder. Other co-products are also produced at different stages of the chain: casein, milk powder and concentrates. For each stage, import and export levels are assessed.*

*Source: Authors*

**Figure 11.** Domestic demand for processed products




*Source: Eurostat, average 2012-2014*

through flow diagrams that track the different processing levels, co-products, imports and exports, etc., as presented on page 5. The cereal and milk sectors are the most complex (**Figure 10**).

**Figure 12** shows the demand for processed products for domestic consumption, including the imported share. Products mainly derived from cereals (bakery products, pasta, other food preparation types) including primary processing products (flour and starch) correspond to the largest category in terms of tonnes processed. This is followed by feed for livestock and pets, including waste from the agri-food industries themselves and oil and protein meals. Drinks represent the third most important sector.

Foreign trade is relatively balanced, with an annual average of 22 Mt of processed agri-food products imported during 2012-2014, and nearly 25 Mt exported.

Processed products with significant imports are oil and protein meal (4.5 Mt) and refined oils (0.78 Mt), meat (1.25 Mt), processed potatoes, vegetables and fruits, drinks, starch and milled products.

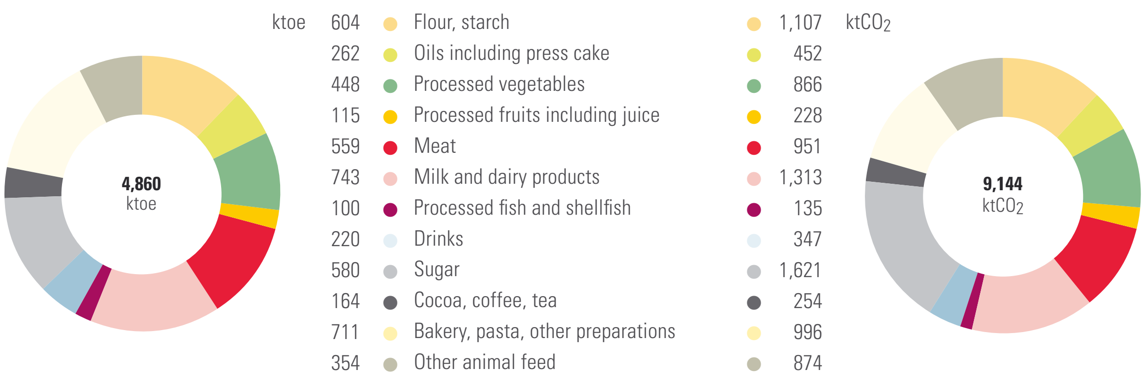
## *Direct energy consumption of the food industry is similar to that of agriculture*

Since foreign trade in processed products is balanced, territorial energy consumption (4.82 Mtoe) and energy footprint (4.86 Mtoe) are similar (**Figure 11**). The order of magnitude is similar to that of the direct energy consumption of the agricultural sector (5.4 Mtoe). The total energy footprint of agricultural production is 8.4 Mtoe (see **Figure 25**).

Similarly, the carbon footprint of processed products (excluding transport), regardless of end uses, is close to the national-level emissions of the food industry, i.e. 9.1 $MtCO_2$. The production of sugar, dairy products and starch products are the main sources of energy consumption and $CO_2$ emissions.

The products with the highest energy consumption and emission factors per tonne produced, in descending order are processed potatoes (1305 $gCO_2/t$), distilled alcoholic beverages (655 $gCO_2/t$), ready meals (396 $gCO_2/t$), sugar, the manufacture of cocoa, chocolate, confectionery products, tea and coffee, butter and cheese (**Figure 12**).

**Figure 12.** Energy and carbon footprint of the processing stage of products consumed in France




*Source: French Ministry of Industry*

# Demand for food-related freight transport

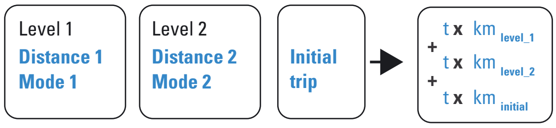
**KEY FIGURES**

- **Household food consumption in France generates transport of around 201 billion t.km annually. And although sea transport accounts for the majority of this figure (57%), given that emissions per tonne of this mode of transport are lower than that of road transport, it is actually road transport that constitutes the bulk of food transport emissions (18.4 $MtCO_2$ or 83%).**
- **Food produced in France represents only 23% of transport, but 47% of emissions.**
- **Airfreight accounts for a very small share of transport demand (0.5%), but its impact in terms of $CO_2$ emissions is significant (1.1 $MtCO_2$ or 5%).**
- **Animal feed transport accounts for one-third of total traffic (mostly meal) and 19% of $CO_2$ emissions. Fruit and vegetables account for one-quarter of total traffic, and 31% of emissions, making it the highest category in terms of transport-related emissions.**

The assessment of the flows of household food-related goods transport is an important contribution of the CECAM project. The Amstram model was used (see box on models, page 7), and the extracted data were reprocessed according to the product categories selected for the project and supplemented by the evaluation of trip distances, both abroad and within the country of origin, as well as the assessment of energy consumption and $CO_2$ emissions of all flows (**Figure 13**).

The domestic and international transport flows presented are related to the annual household food consumption based on the average of 2012 and 2013. The flows relating to the exported products are therefore excluded, as well as the domestic trips of products intended for export.

**Figure 13.** Transport - Trip analysis




Level 1 and 2

The level 1 trip is based on the Sitram survey. It starts in a French department or a foreign country, and the destination is a French department.

The level 2 trip is based on the Amstram model, it is carried out upstream of the level 1 trip. The domestic or international trips of exported products are excluded.

International trips

The SITRAM survey provides the origin and mode of transport, but not the distance of international trips. Sea routes are calculated between the main ports of 227 countries using the CERDI-Distance base.

Initial trip

If the first trip is made in another country, by sea, air, rail or river, we add the distance of the port-capital road trip, if available (with a minimum of 200 km).

### *Imports account for the majority of traffic and GHG emissions*

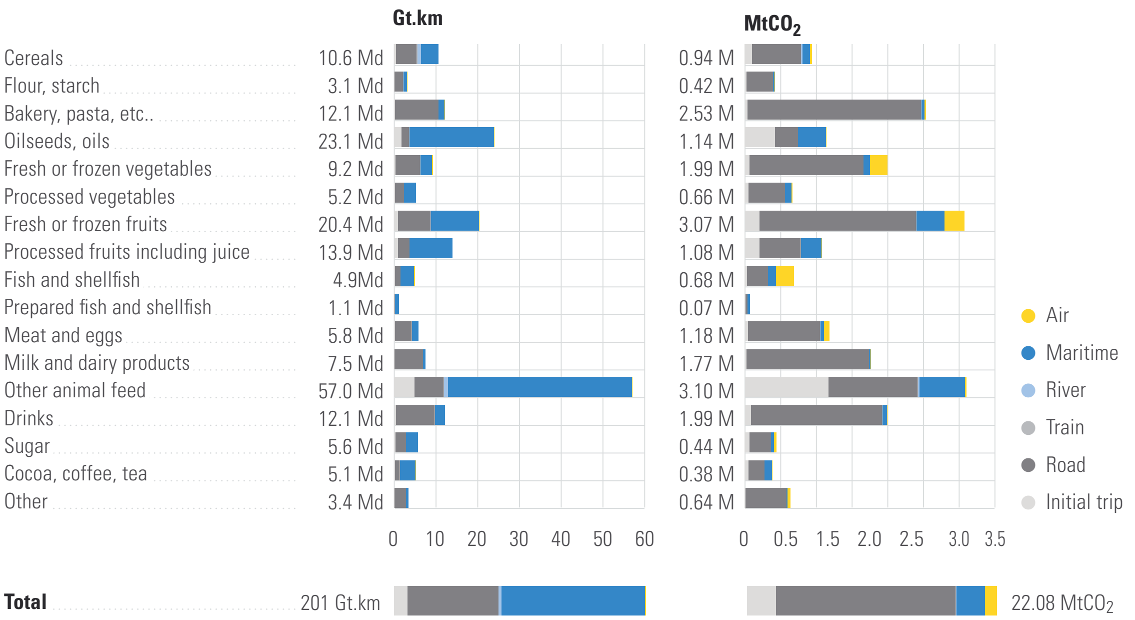
According to our estimates, household food consumption in mainland France generates around 201 Gt.km of food transport, which includes 115 Gt.km by sea and 83 Gt.km by road. Of this total, 23% derives from products of domestic origin, 15% from Europe and 62% from the rest of the world. In comparison, domestic transport for all goods combined, was 282 Gt.km in France in 2013, excluding transit (from the 2014 transport accounts of the French Observation and Statistics Department - SOeS).

**Figure 14.** Total transport by product category


*Source: Authors*

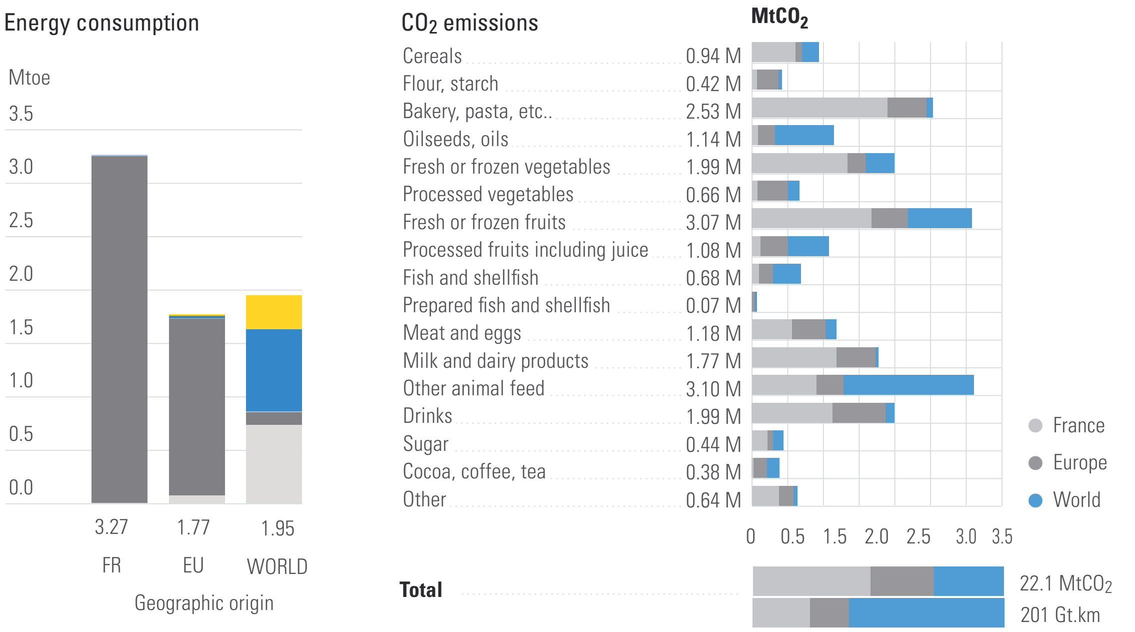
**About 1/3 of cereals and 2/3 of oilseeds are for animal feed*

**Figure 15.** Transportation of food products by mode




*Source: Authors*

**Figure 16.** Food transport by origin

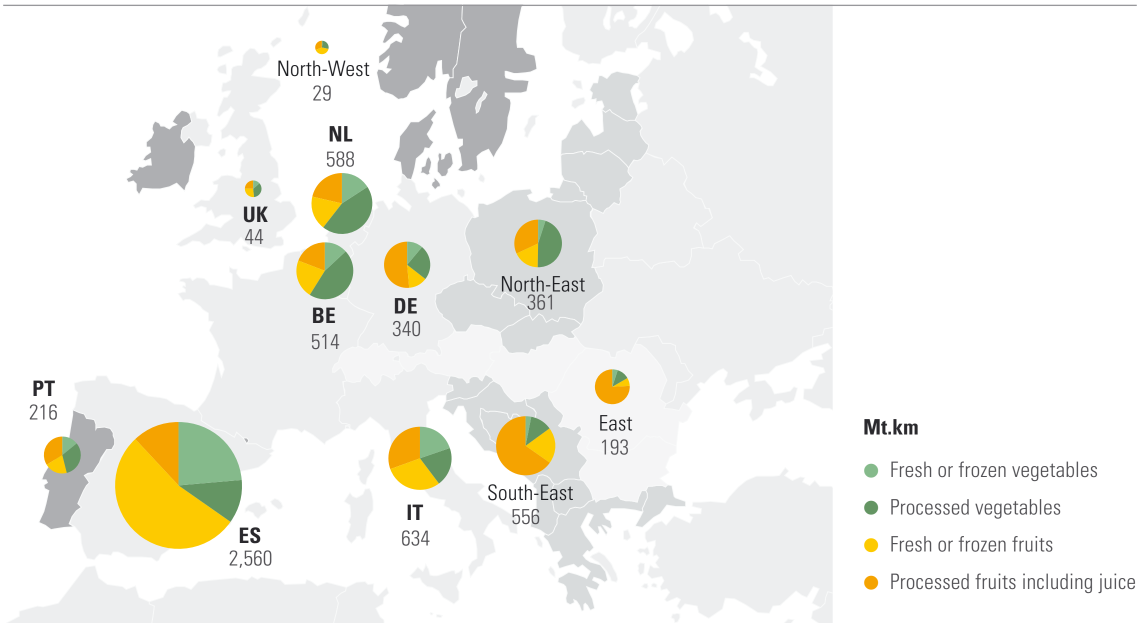



*Source: Authors*

Meal alone generates 49 Gt.km of which 86% is attributable to marine transport. Meal is responsible for a significant proportion of marine transport (36%), along with fruits, oilseeds and oils. Processed food products (excluding animal feed) also have a sizeable impact, representing nearly half of the transport demand (95 Gt. km, or 47%).

Animal feed (other than cereals: meal, milling and industrial residues) represents 27% of freight traffic. With around one-third of cereals and two-thirds of oilseed used for animal feed, the total feed transportation accounts for one-third of total traffic and 19% of transport emissions (4.2 $MtCO_2$). Fruit and vegetables are in second place accounting for 24% of transport (nearly 49 Gt.km, which

**Figure 17.** Distribution of European fruit and vegetable imports




*Source: Authors*

is equivalent to meal alone). Given that fruit and vegetables rely heavily on road transport, this category accounts for 31% of transport emissions. Drinks and cereal-based processed products (bakery products, biscuits, pasta, etc.) also generate a significant amount of traffic: 12 Gt. Km for each of these two categories.

The transport of diverse food preparations and cereal-based products (bakery products, pastries, pasta, etc.) is 12 Gt.km. Road transport represents 85% of traffic. This is followed by sugar, coffee, cocoa and tea, which accounts for 10.6 Gt.km of traffic, including 6.6 Gt.km of marine transport.

Milk and milk products generate traffic of 7.5 Gt.km. Unsurprisingly, this mainly comprises road transport, two-thirds of which originated in France, and almost one-third in Europe. The transport of fresh or processed fish and shellfish, products that are largely imported, is close to that of fresh or processed meat, amounting to 5.9 Gt.km and 5.8 Gt.km, respectively. Fishery products travel long distances by sea, and sometimes by air (see page 17); and meat transport is divided into three origins: France, Europe and World.

## Dairy products generate a higher demand for transportation than meat

A significant proportion of meat consumed in France is imported (20% for bovine meat, and 30-40% for pork and poultry). International trade in pork and poultry is thus relatively significant. The majority of pork imports to France come from Spain (source FranceAgriMer), and the rest from countries to the north of France (Germany, Belgium, Denmark, the Netherlands). Sometimes products are imported from more remote countries, such as beef and lamb from South America and New Zealand, and poultry from Brazil and Thailand. European and intercontinental routes each represent one-third of total transport (1.6 Gt.km) for meat (including processed meats), but account for, respectively, 40% and 15% of $CO_2$ emissions in this category, since intercontinental routes are essentially by sea. Conversely, air transport accounts for 8% of emissions related to meat transport.

On a daily basis we consume twice as much milk and milk products (237g/day) as meat and eggs (107g/day and 13g/day respectively). Total emissions from the transport of milk and milk products (1.8 $MtCO_2$) are thus higher than those from meat and eggs (1.2 $MtCO_2$), although average trip distances are shorter than for meat.

## Fruits and vegetables: preferences and seasonality

According to the INCA 2 survey, French people consume 132 g/day of fruit, 119 g/day of vegetables and 54 g/day of potatoes (food ingested). Fresh or frozen fruits and vegetables generate nearly two-thirds of transport, and processed fruits and vegetables account for the remaining third. Fruits represent two-thirds of the total fruit and vegetable transport, often travelling long distances (citrus fruits, bananas and other off-season fruit). Maritime transport dominates in the transport of fresh, frozen or processed fruit, while the road transport is predominant for vegetables, which mostly come from France or Europe.

As we have seen previously, the volumes of traded vegetables come mainly from France, Europe and Morocco. Tomato is the most consumed fresh vegetable: in 2015, 0.9 Mt of fresh tomatoes were placed on the market, of which 48% were imported. As for many fruits and vegetables, fresh tomato imports mostly satisfy off-season demand. Domestic production of processed tomatoes fell sharply in the 2000s, the trade deficit in 2013 was more than 1 Mt in fresh equivalent.

The most imported fruits are bananas and citrus, the total marketed volumes of which are of the same order of magnitude as apples. Melons are the next most imported fruit (from Spain), followed by strawberries (Spain), pears (Europe and South Africa), and then grapes (Italy). As a result, the transport demand for fruit is higher (34 billion tkm) than that of vegetables (14 billion km) and represents 16% of the total demand for food transport. Bananas alone generate transport of 4.9 billion tkm. Transportation is therefore the largest GHG emitting component of the fruit carbon footprint, while for vegetables, agricultural production remains clearly ahead of transport.

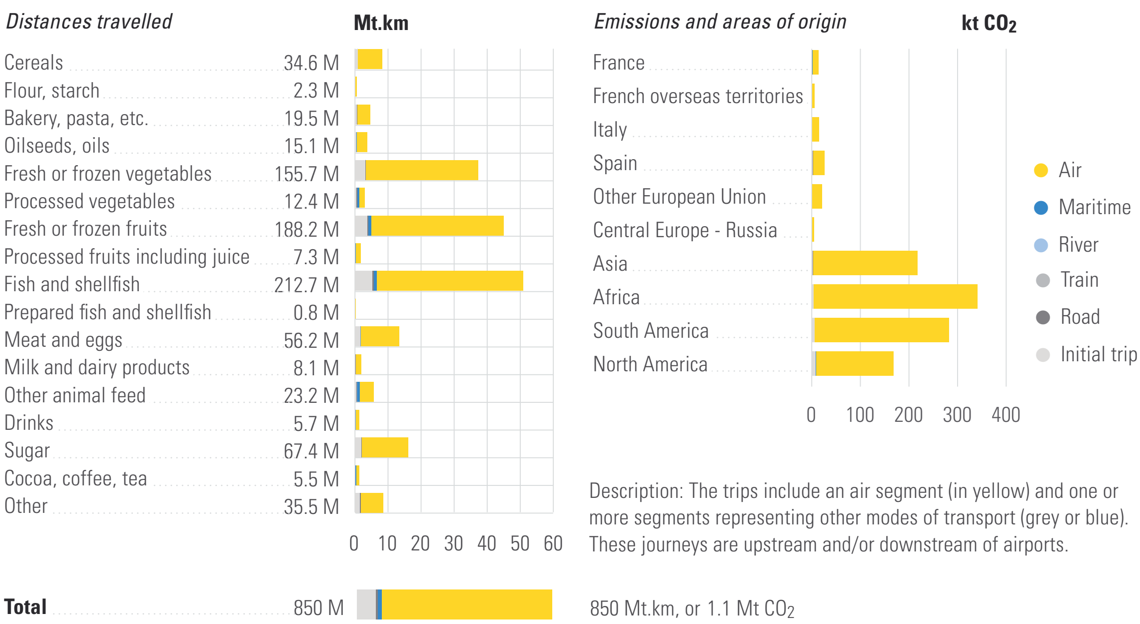
**Figure 18** shows the transport induced by French imports of fruits and vegetables from Europe (in billion tkm). Spain is unsurprisingly the main country of origin of imports. Fresh fruit and vegetable traffic coming from Spain dominates that of processed products. The shares of fresh and processed fruit and vegetables are balanced for Italy, but processed products dominate the transport demand for other European countries. Nearly half of the traffic from Belgium, the Netherlands and north-eastern European countries is for processed vegetables. Traffic coming from south-east and eastern Europe, according to the zones we have defined, is mainly for the transportation of processed fruits.

## *Which products are transported by plane?*

Airfreight of food products represents 742 Mtkm, or 5% of the total, to which must be added 83 Mtkm for road transport, prior to aircraft embarkation in countries of origin (**Figure 18**). The whole traffic ranges to 850 Mt.km.

Fruits and vegetables generate transport of 364 Mtkm, of which 323 Mtkm relates to air travel (i.e. 44% of food air traffic), while fish and shellfish generate 213 Mt.km, of which 185 Mtkm relates to air travel (25% of traffic). These products are shipped over intercontinental distances, with Africa generating the largest amount of air transport.

**Figure 18.** Air transport of food products




*Source: Authors*

# Household trips for shopping and eating out

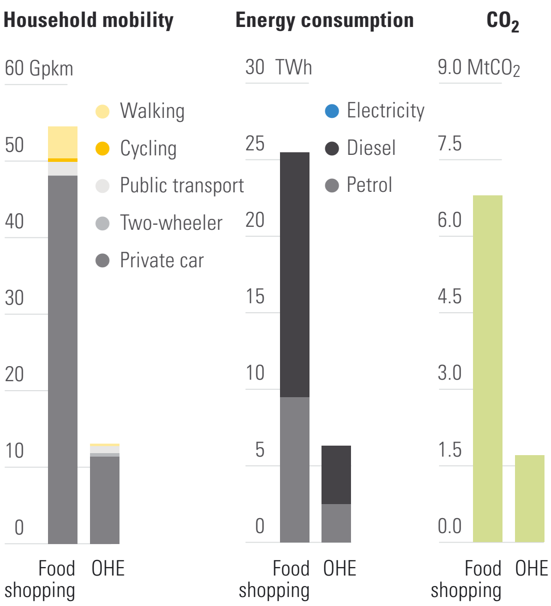
**KEY FIGURES**

- **1,360 km/person/year are travelled for food purchases and out-of-home eating, which leads to emissions of 8.5 $MtCO_2$.**
- **About one in seven meals is consumed away from the home, or 19% of the 1,360 km travelled.**

We focus here on the mobility associated with food consumption, represented by the trips made by households for the purpose of food shopping and for out-of-home eating café/restaurant. Household trips were assessed using the IMMOVE model developed by EDF, based mainly on data from the INSEE National Survey on Transport and Travel 2007-2008 (see box). These trips amount to 68 billion passenger-kilometres per year, i.e. 8% of total mobility and 1,360 km/person/year, mainly by car. Travel for food purchases represents 65% of total travel for purchases. If we consider this mobility according to living standard deciles, the distances travelled increase by 45% from the 10% poorest households to the richest 10%. This can be explained in particular by trips for out-of-home eating, which increase with income. It should be noted, however, that it is the middle classes that have the highest displacements, since the proportion of households in rural areas and suburbs is higher for these categories.

In total, mobility for food shopping and out-of-home eating represents an energy consumption of 31.3 TWh, of which more than 99% is of fossil fuel origin, equating to a total $CO_2$ emissions volume of 8.5 $MtCO_2$. Greenhouse gas emissions generated from out-of-home eating is around 1.7 $MtCO_2$, or 20% of the total. This proportion is 10% for households in the lowest decile and 25% for those in the highest.

**Figure 19.** Household transport for food shopping and out-of-home eating (OHE)




*Source: Authors*

## MOBILITY MODELLING

The IMMOVE model provides a detailed description of mobility, differentiating the total number of trips according to purpose and distance range. The modes used to satisfy the mobility demand, the household-owned private vehicle fleet, the vehicle type, as well as the type of roads used, are described to reconstruct the energy consumption associated with each of these mobility demands. In the 2008 ENTD survey, information was only included on whether purchases were made locally or in hypermarkets. To differentiate the food shopping trips alone, we used an internal study conducted by TNS-SOFRES in 2013 for EDF and the EPFL (Urban Sociology Laboratory) as part of a study on the energy impact of lifestyles. This survey asks individuals about the frequency and distance of their daily trips for the purposes of “food shopping” and “shopping for clothes, equipment, books, music”, within or outside of their neighbourhood. We were then able to recalculate the distance travelled by mode for all “shopping” motives, which could then be compared to the mobility of all the ENTD “shopping” motives, grouping “local shopping” with “hypermarket shopping”. Finally, the model makes it possible to assess the energy consumption associated with this mobility need based on modal shares, vehicle fleets and roads used.

# Distribution of food products and meal preparation at home and out-of-home

**KEY FIGURES**

- **The residential-tertiary emissions relating to food are 11 $MtCO_2$, half of which come from the tertiary sector and half from household homes.**
- **The energy consumption of small establishments dedicated to food (restaurants, small shops, cafes, caterers) is similar to that of supermarkets and wholesalers, around 20 TWh each. However, the emissions of small establishments are higher because of the significance of cooking and the usage of gas.**
- **Collective catering in educational establishments, hospitals and retirement homes accounts for 13% of tertiary sector emissions.**
- **An out-of-home meal emits nearly twice as much as one eaten at home.**

The residential and tertiary sectors represent 9% of the total carbon footprint and 25% of the energy demand (excluding household transport), each sector accounting for about half. The aim here is to isolate food-related energy consumption from the residential and tertiary sectors. The scope of assessment of energy consumption is presented in Tables 2 and 3.

## *Multiple types of tertiary establishments*

We considered energy consumption for food provision in tertiary sector buildings including out-of-home eating, supermarkets, grocery stores and small food businesses.

It is important to distinguish between establishments whose activity is not related to the production of goods and services intended primarily for food provision, but which provide meals to their employees or to their residents and, on the other hand, establishments whose activity is partially or entirely geared towards goods or services for food provision, such as restaurants, bakeries and supermarkets (**Table 2**).

The results show that establishments not dedicated to food production account for a very small share of energy consumption, around 20%, of which three-quarters is for public establishments such as schools, retirement homes, and hospitals (**Figure 20**). Wholesale sites and supermarkets account for 40% of consumption, i.e. about as much as restaurants and small food businesses. It is interesting to note that establishments dedicated to the production of foodstuffs, such as food shops and restaurants, are much more likely to use thermal cooking and thermal processes, while logistics and distribution establishments use more lighting and automation. As a result, the former rely more on fossil fuels and the latter on electricity.

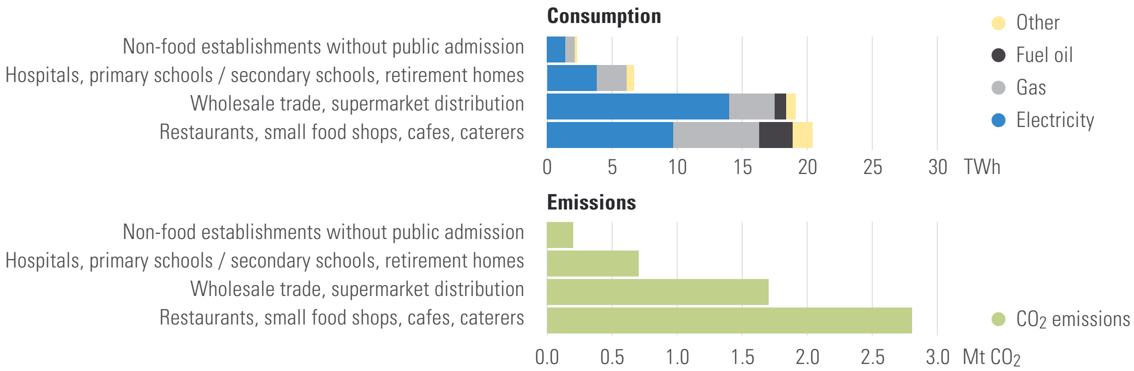
In terms of energy uses, three uses account for almost 75% of total energy consumption in the tertiary sector for food (**Figure 21**). Cooking accounts for 31% of energy consumption, of which 50% is fossil fuels, heating represents 25% of consumption, of which 80% is fossil fuels, and finally food refrigeration represents 17% of consumption,

**Table 2**. Scope of assessment of energy consumption by type of tertiary establishment

| Establishments considered | Uses | Indicators |
|---|---|---|
| Non-food establishments without public admission | Cooling and cooking for employees | Energy consumption by use, non-export turnover and number of full-time jobs by sub-sector |
| Hospitals, Primary Schools/ Secondary Schools, Retirement Homes | Cooling and cooking for employees, pupils and residents | Energy consumption by use, turnover and number of full-time jobs by sub-sector |
| Wholesale, large-scale retail | Cooling, cooking, heating, DHW, specific electricity and others | Energy consumption by use, share of food products in turnover |
| Restaurants, small food shops, cafes, caterers | Cooling, cooking, heating, DHW, specific electricity and others | Energy consumption by use |
| Hotels without restaurants<br>Hotel restaurants | Cooling and cooking<br>Cooling, cooking, heating, DHW, specific electricity and others | Energy consumption by use<br>Energy consumption by use, share of catering activity in turnover |

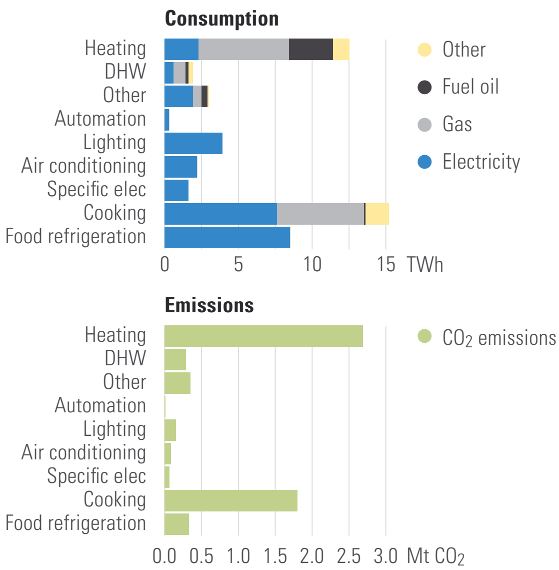
Sources: We mainly used the INSEE ESANE database and CEREN data which provides the consumption of 27 sub-sectors, according to 9 energy uses: heating, domestic hot water, cooking, food cooling, lighting, air conditioning, automation, specific electricity and others. $CO_2$ emissions are estimated based on the baseline emission factors of ADEME's 2014 Carbon Base.

**Figure 20.** Energy consumption and greenhouse gas emissions by establishment type




*Source: Authors*

**Figure 21.** Energy consumption and greenhouse gas emissions from establishments by use




*Source: Authors*

all of which is electricity. 80% of other uses is provided by electricity. Regarding $CO_2$ emissions, logically it is the uses that depend on fossil fuels that have the greatest impact. Thus, cooking and heating alone represent 47% and 31% respectively, i.e. 78% of tertiary emissions for food.

The total energy consumption of these tertiary establishments is 49.2 TWh, of which nearly 60% is electricity, while $CO_2$ emissions represent a volume of 5.6 $MtCO_2$.

## *Energy consumption for food at home*

The uses related to "food" provision at home include refrigeration for the storage of food, using chilling and freezing appliances, the preparation of meals and therefore the various appliances used for cooking, and also food processing, and finally dishwashing (**Table 3**). Given that food provision is only one way that the occupants of a household use energy, we initially chose not to allocate any energy consumption related to living in a household, such as heating or lighting, making the assumption that other activities requiring these uses would have been carried out anyway. This corresponds to the standard classifications in terms of how housing functions are linked to the household carbon footprint.

**Table 3**. Scope of home energy consumption assessment

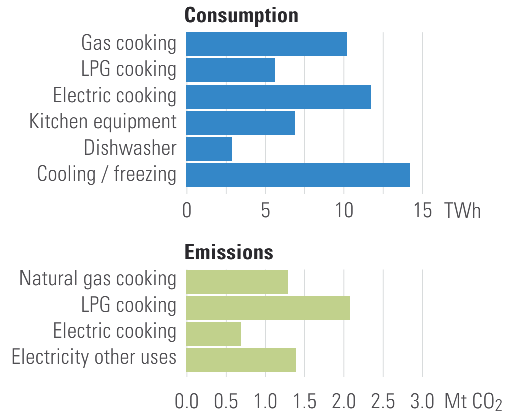
| |
|---|
| Cooking appliances (gas, LPG, electricity) |
| Small electrical equipment (microwave, kettle, toaster, processor, etc.) |
| Dishwasher |
| Refrigerators, freezers |

In total, cooking (oven and hob) represents 53% of residential energy consumption for food, but 75% of $CO_2$ emissions, due to the use of highly carbon-based fossil fuels for this activity (**Figure 22**). Refrigeration is the second largest item of energy consumption. The total consumption of energy related to food at home is 51.5 TWh (4.4 Mtoe) of which nearly 70% is electricity, while $CO_2$ emissions represent a volume of 5.5 $MtCO_2$.

### LEAKAGE OF HFC REFRIGERANTS

Given the significance of refrigeration, we have estimated the losses of refrigerants resulting from "air conditioning" and "cooling" in the residential and tertiary sectors. For this purpose, the emission inventories provided by CITEPA [13] were used. We determined the proportion of food-related uses for air conditioning and food refrigeration, based on calculations previously carried out to obtain the total HFC volumes for food. Finally, based on global warming potential (GWP), we calculated the amount of refrigerant leakage to be 2.1 $MtCO_2eq$ for the tertiary sector, and 1.8 $MtCO_2eq$ for the residential sector, i.e. total losses of 3.9 $MtCO_2eq$.

**Figure 22.** Home energy consumption and greenhouse gas emissions



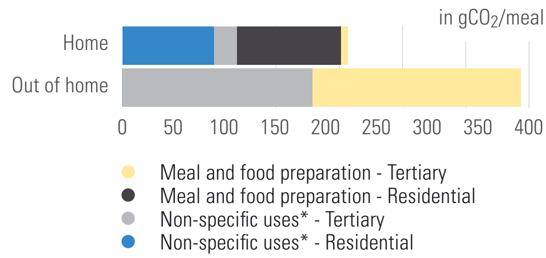

*Source: Authors*

## *Out-of-home meals have higher carbon footprints than meals at home*

Based on the INCA2 study, supplemented with data on the population living outside the household, we estimate that the total number of meals eaten by the mainland population amounts to 66.0 billion meals per year, of which 55.7 billion were eaten at home and 10.3 billion were eaten away from the home. This latter figure is consistent with the GIRA Conseil report, which presents a figure of 10 billion meals eaten outside of the home. This equates to one in every seven meals being eaten out-of-home. The energy consumption of the tertiary sector, calculated previously, was allocated to home and out-of-home eating, based on precise details of activity sub-categories.

Regarding meals at home, we considered here the share of heating and lighting in the home dedicated to food, on the basis of the time dedicated to this function per person during the day: eating meals, preparing meals, dishwashing, and clearing the table. Based on the 2010 INSEE time use survey, the average time spent in relation to food is about an hour and a half, i.e. 10% of time use.

**Figure 23.** $CO_2$ emissions per meal by location




**proportion of heating / DHW / lighting / other allocated to food*

**Figure 23** shows the results in terms of $CO_2$ emissions per meal. It appears that energy consumption associated with out-of-home meals is twice as high as that of meals at home. If we consider only the energy consumption dedicated to food provision for meals at home, that is to say without taking into account heating or lighting, this becomes three times as much. This raw result may seem counterintuitive because out-of-home eating is considered to be quite efficient due to the economies of scale associated with culinary preparation.

It is interesting to note that a large proportion, around 40-45%, of energy consumption and $CO_2$ emissions associated with eating out-of-home comes from energy uses that are not specific to meal preparation. These are heating, domestic hot water, and lighting of the establishments dedicated to food provision: restaurants, canteens, and cafes. Moreover, if we only consider energy uses specific to meal preparation (cooking, refrigeration, kitchen appliances...) the average energy and $CO_2$ content related to an out-of-home meal are about 1.8 times greater than those of a meal at home.

# Overall energy and carbon footprint of food

In terms of the scope chosen for this study, greenhouse gas emissions from household food consumption in France amounted to 163 $MtCO_2eq$, i.e. 24% of the household carbon footprint in France in relation to the total carbon footprint estimated by the SOeS of 671 $MtCO_2eq$ for 2012.

Agricultural production is the largest GHG emitter with a total of 109 $MtCO_2eq$, i.e. two-thirds of the total carbon footprint of food consumption (**Figure 25**). Methane ($CH_4$) accounts for 29% of this total balance and 44% of emissions from agricultural production. This is derived from enteric fermentation by ruminants and livestock effluent. Nitrous oxide ($N_2O$) accounts for 23% of the total carbon footprint and 34% of agricultural emissions. This mainly derives from the manufacture and use of nitrogen fertilizers on agricultural soils. The amount of meat in our diet, along with the agricultural practices used, are therefore crucial components of this carbon footprint. Lastly, $CO_2$ from agricultural production accounts for 22% of emissions from agriculture. This derives from the direct energy consumption of farms (equipment and buildings) and the indirect emissions related to the provision of other inputs (other fertilizers, plant protection products, manufacture of equipment and building construction).

The second highest sector in terms of total GHG emissions is the transport sector. Indeed, freight transport and household transport in relation to food represents 19% of the total carbon footprint, i.e. 30 $MtCO_2$. Road freight transport accounts for a large proportion of these emissions, with 23 $MtCO_2$, of which 43% is for domestic products and 57% for imported products (considering the total journey from the country of origin to the destination in France). Bringing the production areas closer to the places of consumption is therefore a major issue, including for processed products. Marine transport accounts for almost one-third of traffic in t.km travelled, but is much less significant in terms of carbon footprint (11%), since emissions per tonne.km are much lower than for road transport. Conversely, air transport represents a small amount of traffic (0.5%), but a relatively high proportion of freight transport emissions (5%).

### *Identifying the potential for reducing energy demand*

Globally, the main greenhouse gas produced in relation to food is $CO_2$, which accounts for 46% of the total carbon footprint. This footprint derives from energy consumption at all of the different stages of the food system. Reducing energy demand is therefore the first essential step in GHG emission reduction strategies, whether such strategies target structural measures to limit needs, or energy efficiency measures. Secondly, decisions regarding the energy mix will remain important in determining the final carbon footprint.

The total energy consumption is around 31.6 Mtoe (**Figure 24**). The transport sector accounts for the largest share of this energy footprint, i.e. 31%, of which 22% is freight-related and 9% comes from household travel, followed by the agricultural sector with 27% of energy consumption. The three others sectors, the food industry, the residential and tertiary sectors, represent respectively

**Figure 24.** Energy balance by sector

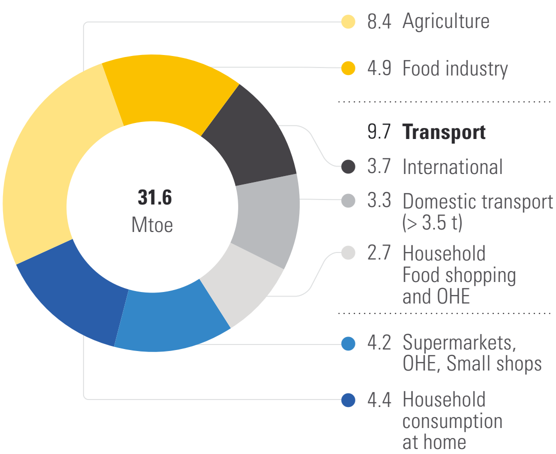
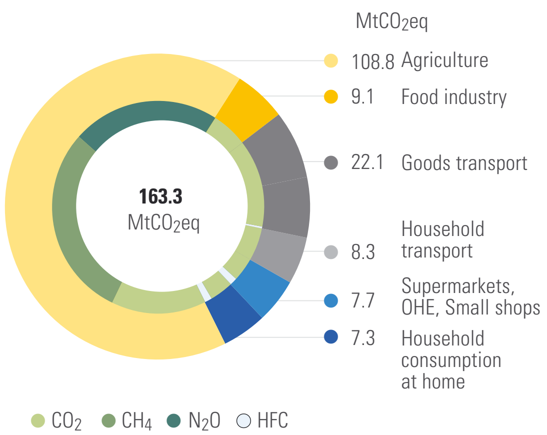



**Figure 25.** Carbon balance by sector



15%, 14% and 13% of energy consumption. With over a quarter of the energy footprint of food, residential-tertiary is therefore far from negligible. This observation is supported by the fact that the energy consumption associated with an out-of-home meal is twice that of a meal at home.

In terms of the energy footprint of food per energy source, fuel is the main item of energy consumption (39%). The consumption of natural gas (8.6 Mtoe, or 27%) is primarily due to the production of nitrogen fertilizers and processing by the agri-food industries. Electricity also accounts for 27% of the balance sheet (8.4 Mtoe), of which 3 Mtoe is in the home and 2.5 Mtoe is related to the tertiary sector.

## *Challenges related to meat-based diets and nitrogen inputs*

It is clear that changing household diets towards less meat and the reduction of the use of nitrogen inputs for all types of agricultural production are major challenges for a strategy to reduce greenhouse gas emissions. A simulation carried out in the framework of the CECAM project shows that a diet that reduces meat and dairy product consumption by approximately half in favour of an increase in the consumption of plant-based foods, together with a change in agricultural practices towards less inputs and a reallocation of agricultural land, would enable a halving of the carbon footprint of agriculture. It would also lead to a 25% reduction in import-related freight transport emissions, simply due to a decrease in freight volume. The potential to reduce greenhouse gas emissions downstream of the food system is more diffuse but can be significant, such as the reduction of losses, the reduction of the need for transport, along with a modal shift and technological advances in equipment.

## *A scope that can be widened*

The only study that, to our knowledge, has evaluated the carbon footprint of food in France using a global approach, is that carried out by IFEN in 2006. The total balance was very close to the one evaluated here: 170 $MtCO_2eq$. The results for the food industry, the residential and tertiary sectors are consistent. However, the items taken into consideration differed slightly: the impact of packaging was taken into account by IFEN, but not the indirect emissions from agriculture. The scope considered for freight transport was only domestic and therefore relatively limited; conversely, the significance of household trips was higher than our estimates.

We can consider that the evaluation of greenhouse gas emissions by the CECAM project is relatively conservative since, as indicated at the beginning of this booklet, a few other emissions sources should also be taken into account: light-duty vehicles, packaging and waste processing in particular. In some instances, data on the carbon content of imported products are weak.

## *Simulations and decision support tools*

The simulation tools developed in this project enable the evaluation of the carbon and energy impact of scenarios for a change in the food system. A number of assumptions could be formulated, particularly regarding:

- Changes in food consumption in France, possibly according to population segments.
- Changes in land use and agricultural practices, and also international trade.
- Changes in the distribution of food products to households, with increased use of online shopping for example.
- Reduction of losses and wastage, and the valorization of waste and organic by-products (animal feed; material, energy and agronomic recovery).
- Consideration of technological progress at all stages of the food system.

Beyond the environmental aspect, the description of alternative food systems in each scenario would reveal the impact of changes made within the food system configuration: the agricultural area mobilized for food needs and the area available for other uses, the allocation of land for agricultural production, the possible consequences for the food sector, the configuration of the demand for transport in all its components, and the configuration of distribution networks, for example. The tools developed are relevant to inform discussions on the design of low carbon strategies at the national or regional scales, and to inform the decisions of actors.

# Energy and carbon footprint of food in France

*from production to consumption*

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