Environmental impacts of French households' final consumption

Laurent Meunier
ADEME
27 rue Louis Vicat
75737 Paris
France

Isabelle Vincent
ADEME
27 rue Louis Vicat
75737 Paris
France
isabelle.vincent@ademe.fr

Eric Vidalenc
ADEME
27 rue Louis Vicat
75737 Paris
France
eric.vidalenc@ademe.fr

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Abstract

In order to fight against climate change, ambitious targets have been set, such as decreasing carbon emissions by 75 % in France compared to 1990. Yet, focusing on territorial impacts leads to overlook import-embedded impacts. As a matter of fact, French territorial greenhouse gases (henceforth GHG) emissions have slightly decreased since 1990, whereas consumption-based emissions have been shown to increase. This is why we focus in this paper on consumption-based emissions rather than territorial emissions. Moreover, other environmental impacts than GHG emissions are taken into account: air acidification (ACD), photochemical oxidation (PCO) and non-dangerous industrial wastes (NDIW).

In a nutshell, this paper provides a prospective analysis of the environmental impacts of household final consumption, which shows, among other, that even if ambitious territorial objectives were achieved by 2030 regarding GHG emissions, consumption-based impacts would be out of the 2 ° pathway. Indeed, imports-embedded impacts will be hard to curb by 2030. However, further analysis is needed in order to understand whether the main driver is the level of consumption, or the conditions of production abroad.

Introduction

Following the Intergovernmental Panel on Climate Change recommendations, some countries set ambitious greenhouse gases (henceforth GHG) emissions reduction targets. In particular, France officially committed to a four-fold reduction in its territorial GHG emissions by 2050 compared to 1990 levels.[1] In this context, 2030 is an important step on the road towards a 2050 low-carbon society: emissions in 2030 will have to comply with the self-imposed 75 % decrease in GHG emissions by 2050, were France to meet it. Yet, focusing on territorial impacts leads to overlook import-embedded-impacts. As a matter of fact, French territorial GHG emissions, the distribution of which is given in Figure 1[2], have decreased by 0.6 % per year since 1990 (CITEPA, 2013).

On the other hand, consumption-based emissions have been shown to increase by more than 0.2 % per year (author's computations from Bio Intelligence Service, 2011). Moreover, focusing on consumption-based emissions has other virtues: first, microeconomic theory teaches us that (final) consumption is what matters for individual consumers; secondly, it can be interpreted in terms of every-day-life final services. This is why we focus on consumption-based emissions rather than territorial emissions. The relevance of consumption-based analysis of environmental impacts can be appreciated by the increasing related research.

As far as environmental impacts are concerned, GHG emissions, air acidification (ACD), photochemical oxidation (PCO) and non-dangerous industrial wastes (NDIW) are taken into account. This paper helps answer the following questions, among others: first, to what extent are the import-embedded impacts important? Then, to what extent environmental im-

1. See the 2005 Energy Policy Programming Bill (loi POPE).

2. Air and sea international bunkers are excluded. Moreover, land-use changes not taken into account.

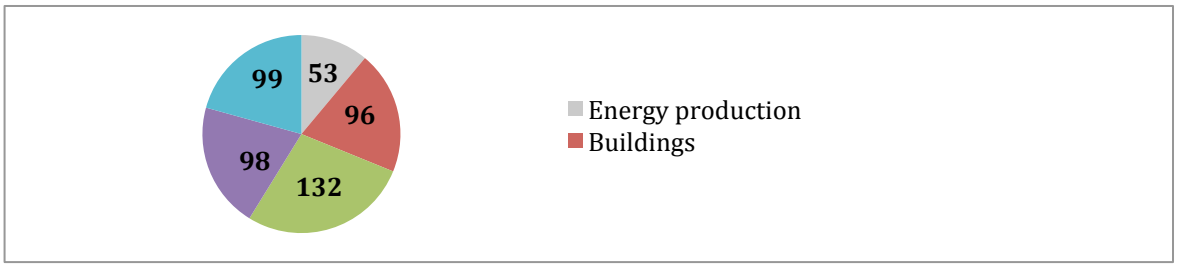

Figure 1. French national GHG emissions in 2012, Mt CO_2eq. Source: CITEPA, SECTEN Report, 2014.

pacts can be decreased when current ways of living are protracted? Last but not least, to what extent are the answers to the previous questions reliable? In the following section, we describe the quantitative method. Then, we give an overview of the environmental impacts of French households final consumption and the scenarios aiming at decreasing those impacts. The fourth section presents the performed simulations. Finally, results are presented, and their reliability discussed.

Consumption and environmental impacts

OVERALL METHODOLOGY

The results presented in this paper focus on the quantitative component of a broader prospective exercise which was carried out within ADEME[3]. The following steps have been implemented:

- First a diagnosis was established regarding the current trends and impacts of French households' final consumption. Different working groups have been set up on housing, transport, nutrition, equipment goods, recreation and culture, health, education, in order to identify production and consumption drivers on these sectors. Moreover cross-cutting issues were selected such as economic growth, individual and collective values, circular economy, sharing economy, the so-called silver economy (i.e. referring to the growing market made up of elderly solvent people), information and communication technologies, etc. Deep trends as well as shallower evolutions were sought for those.
- Then hypotheses on demand, intermediate consumption and per-unit impact aiming at decreasing environmental impacts have been proposed based on the drivers identified. These hypotheses have been formulated both for a reference scenario as well as an "alleviated environmental footprint" scenario.
- Last, a quantification of the prospective exercise's results in terms of environmental impact has been carried out, thanks to an input-output modelling tool. The description of the latter step is the object of the paper.

CONSUMPTION STRUCTURE

In order to make the interpretation easier, results are given according to the "Classification of Individual Consumption according to Purpose" (henceforth COICOP), which is an aggregation of heterogeneous products (i.e., goods and services) into "functions", or "final services" (e.g., "food", "clothing", "transport", etc.). It should be emphasized that even if there is much heterogeneity in the share of each function across both time and countries, France in 2007 was relatively close to the UE27 average in 2005 (see Eurostat's Household Budget Survey[4]).

MODELLING THE ENVIRONMENTAL IMPACTS OF HOUSEHOLDS' FINAL CONSUMPTION

General description of the modelling methodology

The quantitative analysis presented in this paper is performed by soft-linking two modelling tools. First, a bottom-up, techno-economic, energy consumption model (Medpro®) helps us simulate France's energy balance. Final energy consumption is then converted into spending. Finally, expenditures are plugged into our multi-regional environmentally-extended input-output model.

Basics of input output analysis and environmental extensions

In addition to households final consumption, the effective consumption includes by definition government-provided private goods and services (e.g. health services). In our analysis, we also take households investment in dwellings construction and retrofitting into account[5]. From now on, any reference to "effective consumption" includes investments in dwellings. On the other hand, we exclude exports as well as government-provided public goods and services (i.e. national defense services). Furthermore, both domestic as well as foreign production needed to satisfy this consumption level is taken into account.

As far as imported final consumption is concerned, input-output analysis is replicated on two trading-partner economies assumed to represent the set of France's trading-partners. Concerning intermediate goods, the computations are slightly more complicated: domestic final consumption is first turned into necessary domestic production. Then, using the imported per-

3. ADEME: French Environment and Energy Management Agency. ADEME a Public Agency in the field of energy efficiency and renewable energy, under the authority of the Ministry of Energy, Environment, Sustainable Development and Research. It provides advices for the Government (on policies and measures) and develops tools for companies and local authorities, carries out awareness campaigns and delivers information to a large public, supports heat production investments based on renewable or domestic waste fuels, supports research and innovation for green technologies.

4. Final consumption expenditure of households by consumption purpose – COICOP 2 digit – aggregates at current prices, Eurostat, 2014, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_co3_c&lang=en.

5. This is not standard in the national accounts literature, but for the sake of completeness dwellings construction environmental impacts have to be taken into account. Though this strengthens the importance of "Housing" (investment in dwellings accounts for about 8% of the French effective consumption, see INSEE), it does not challenge any conclusion.

Table 1. Relative French effective consumption spending in 2007, by COICOP.

Code	Label	Spending (%)
01	Food and non-alcoholic beverages (*)	11.6
02	Alcoholic beverages, tobacco and narcotics (*)	0.4
03	Clothing and footwear	2.7
04	Housing, water, electricity, gas and other fuels (*)	30.0
05	Furnishings, household equipment and routine household maintenance (*)	4.1
06	Health	15.1
07	Transport	8.7
08	Communication	1.8
09	Recreation and culture	6.4
10	Education	7.4
11	Restaurants and hotels	4.7
12	Miscellaneous goods and services	6.9
	Total	100.0

Source: United Nations (COICOP) and INSEE (spending). (*) Henceforth, "Food", "Alcohol, "Housing" and "Furnishings and equipment" respectively.

unit intermediate consumption tables, the needed quantity of intermediate products to be imported is determined. Finally, the origin of imports is assumed according to each country's share in the imports[6], and an input-output analysis is performed on each of the two countries.

Thanks to these previous computations, we know the quantity of each of the goods and services the domestic economy as well as the trading-partner economies have to produce in order to satisfy the domestic households effective consumption. Combining these estimates with the per-monetary-unit impacts gives us the environmental impacts of the domestic households effective consumption, to which we add the direct impacts due to fuel burning.

Our model

The input-output model we built is multi-regional. There is one core-country (France) and two trading-partner economies: Germany, assumed to represent the relatively rich countries; and Poland, assumed to represent the other countries. As imperfect as it might seem, the lack of data lead us to make such a choice. Therefore, production systems and per-unit environmental impacts heterogeneity is taken into account. To illustrate this point, let us notice that Polish power generation per-unit CO_2 emissions (2008–2010 average) are fairly close to Chinese's and 70 % higher than German's: 798 gCO_2=kWh, 790 gCO_2=kWh and 468 gCO_2=kWh respectively

(International Energy Agency, 2012). Eurostat national accounts data (NACE 2007 rev. 1) are used, in which economies are disaggregated in 59 products (i.e. goods and services). In addition to final consumption spending, production and intermediate consumption, some primary flows (or pollutants, then converted into environmental impacts) are available for the 59 products. This enables us to conduct a multi-regional environmentally-extended input-output analysis.

Scenarios are built first by making the economy growing, and secondly by altering the following coefficients:

- Final consumption.
- Intermediate consumption.
- Per-unit environmental impacts.

Environmental Impacts: diagnosis and actions to decrease them

ENVIRONMENTAL IMPACTS OF THE FRENCH HOUSEHOLDS CONSUMPTION IN 2007

Let us start with two important observations: first, impacts are concentrated on a few consumption purposes; secondly, consumption-based impacts of products are extremely heterogeneous – both in level and structure. Indeed, we confirm that food, housing and transport contribute roughly more than ⅔ of each of the four impacts considered. Yet, as shown in Table 2 the importance of the top contributor is not homogeneous across impacts[7].

Figure 2 gives the decomposition of GHG emissions across purposes, where:

6. The weight of each country is estimated for the n products, based on UN Comtrade database.

7. Technically speaking, these are potential environmental impacts. Moreover, masses of wastes are not properly a potential environmental impact. However, they raise potential treatment challenges which is why they are taken into account.

Table 2. Top-contributors to environmental impacts, France, 2007.

	GHG	ACD	PCO	NDIW
Top-contributor	Housing	Food	Food	Housing
Top-contributor share	28 %	47 %	27 %	70 %
Top-three contributors share	73 %	72 %	67 %	80 %

Source: Authors' computations.

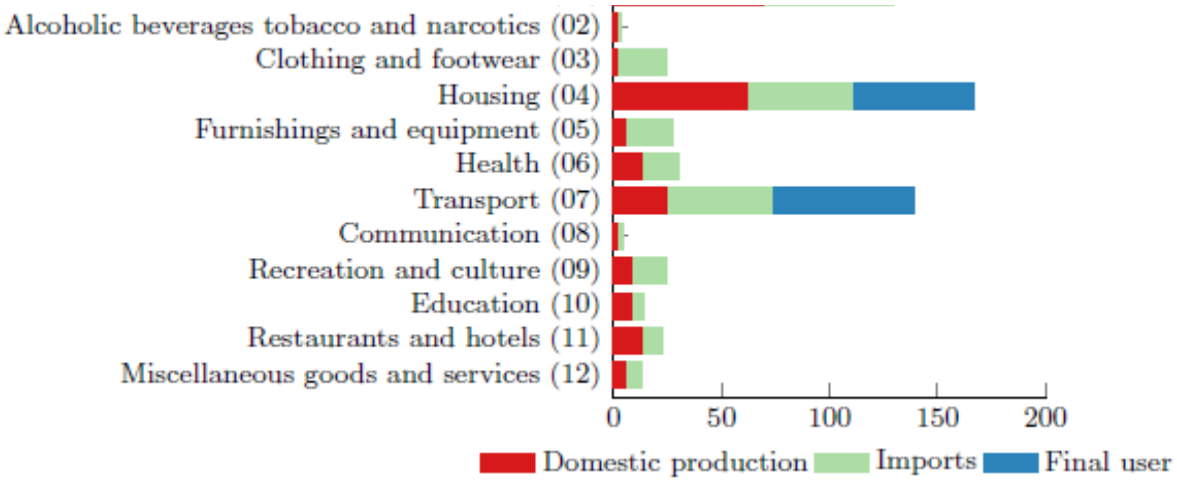

Figure 2. French consumption-based GHG emissions in 2007, Mt CO_2eq. Source: Authors's computations.

- "Domestic production" stands for the GHG emissions caused by the production of goods that took place in France;
- "Imports" refer to the GHG emissions caused by the production (both final products and intermediate consumption) that did not take place in France;
- "Final user" stands for the GHG emissions caused directly by the final user, i.e. motor fuels for transport, heating fuel, natural gas and coal for heating.

The environmental impact of each function is the result of the combination of the amount spent and its per-monetary-unit impact. In monetary flows, the top-three contributors account for half of the effective consumption spending (see Table 1).

REDUCING ENVIRONMENTAL PRESSURES: OVERVIEW OF THE SCENARIOS

Two scenarios are simulated: first, the reference scenario, in which current trends are not challenged; second, the ambitious scenario, in which ambitious changes in consumption are simulated. The reference scenario is a reference point, and it must not be interpreted as a "business-as-usual", or even worse, as "the most likely scenario". Indeed, some strong assumptions are made precisely to neutralize some important effects. Basically, apart from a larger and richer population, everything stands – relatively – as in 2007, the base year. Note that some progress on energy efficiency is assumed, yet not faster than current trends (about 1 % per year, see CEREN 2010). In the ambitious scenario, actions aiming at decreasing the environmental impacts of households' final effective consumption are considered. All sectors are involved to achieve a more sustainable final consumption, and the focus is energy and carbon emissions. Most of these assumptions come from a previous study by ADEME (ADEME, 2013). Here is a qualitative review of the actions a priori aiming at decreasing environmental impacts that have been simulated. They are summarized in Table 4.

Housing (COICOP 04)

3 sets of actions are simulated. First, dwellings' thermal performance is strongly increased through a massive refurbishment: 500,000 dwellings a year, to be compared with the current 150,000 (OPEN, 2013). The consequence is twofold: on the one hand, the final demand for "Construction" products (i.e., retrofitting activities) increases; on the other hand, both households energy consumption (and thus energy spending) and direct carbon emissions decrease. Secondly, new dwellings construction is assumed to be fixed (which corresponds to a decrease in new dwellings per capita) at about 350,000 dwellings per year. Finally, per-unit intermediate consumption of timber is assumed to increase (by 10 % compared to current levels) and thus substitute non-metallic minerals.

Transport (COICOP 07)

Some technological progress, organizational improvements (e.g. car-sharing) and tailored vehicles (e.g., small and light electric cars for intra-city trips) lead to a decrease in both energy consumption (and thus energy spending and direct carbon emissions) and to the number of new car registrations.

Energy efficiency is also improved in the transport services. In addition, car manufacturing is assumed to (intermediately) consume a lower quantity of steel.

Food and drinks (COICOP 01 & 02)

First, agricultural processes are improved: both N_2O and CH_4 per-unit emissions are assumed to decrease. Thirdly, a 25 % decrease in energy consumption is achieved. Finally, a drastic reduction in food throwing away is assumed (-60 % relative to current levels).

Equipment and maintenance (COICOP 03, 05, 08)

3 assumptions are simulated: first, equipment life-cycle duration are increased (by 20 %); second, energy efficiency of appliances is greatly improved though without any technological disruption. For example, refrigerators are assumed to be as energy efficient in average in 2030 as the currently most energy efficient ones. Finally, over-dosing of chemical products (detergents, phytosanitary products, glues, varnish, paint, etc.) is assumed to decrease.

Others (COICOP 06, 09, 10, 11, 12)

Thermal usages energy consumption in services buildings is assumed to decrease, thanks among other to refurbishments. Moreover, carbon emissions caused by power generation are decreased by two thirds. Finally, industry is globally assumed to improve its per-unit energy efficiency by 20 %. More details can be found in ADEME, 2013.

Simulations

THE FRENCH ECONOMY IN 2030

Households final consumption expenditure is assumed to grow along with the (exogenously determined) real GDP. Then, this increase in spending is converted into an increase in physical quantities on the one side, and an increase in value on the other side. Two forces make physical quantities increase: first, demographic growth (+11 % over the period 2007–2030); second, the poorest 20 % are assumed to spend their increase in income into buying more units of goods and services rather than buying higher-value goods and services, unlike the 80 % other. In other words, the growth of consumption per capita is immaterial but for 20 % of the population. Assuming fixed budgetary coefficients as well as fixed (after-tax) income distribution (thus only one tenth[8] of the increase in national income is "physical"), we obtain a projection of the households consumption in 2030. The direct consequence is that physical quantities increase by 14 %, and the value of goods by 23 %. Moreover, as budget coefficients are fixed, prices of all goods and services increase at the same rate. Though this is a very strong assumption, this was done on purpose precisely not to interfere with the actions aiming at decreasing the environmental impacts. Moreover, as budget coefficients are fixed, prices of all goods and services increase at the same rate. Though this is a very strong assumption, this was done on purpose in order not to interfere with the actions aiming at decreasing the environmental impacts. The comparative static analysis (see below) helps appreciating the extent to which results are sensitive to assumptions on budgetary coefficients. It is important to notice that we are interested in potentials: we neither look for optimality nor cost-effectiveness. In other words, the model we use is a simulation model, and not an optimization model, giving us the order of magnitude of changes in environmental impacts subsequent to changes in consumption patterns, per-unit intermediate consumption and per-unit impacts. Finally, among the simulated actions, some (e.g., reducing food wastes, car-sharing) have insignificant cost while others entail additional costs that are taken into account (ex: dwellings retrofitting). Others do entail additional costs but these have not been taken into account. As a consequence, total environmental impacts are likely to be overestimated: Income and spending being constant, an increase in any cost makes households 'purchasing power decrease.

8. I.e. the share of the national after-tax income earned by the poorest 20 % is 10 %, see INSEE 2013).

PLUGGING THE ASSUMPTIONS INTO THE MODEL

Two different sets of hypotheses are applied to the projection of French economy in 2030: a set of moderate changes, corresponding to the reference scenario, and a set of deeper changes, corresponding to the main scenario. In each scenario, assumptions are made on: the final demand, the technical coefficients – though most of them remain unchanged – and finally production per-unit environmental impacts. As far as final demand is concerned, we quantify the possible additional spending (e.g., investments to insulate homes) as well as the related economic gains (e.g., a decrease in energy spending subsequent to an increase in energy efficiency), and thus estimate the (possible) net "avoided" spending. In order to control for possible rebound-effects, we redistribute the net avoided expenditure according to the budgetary coefficients observed in 2007. The input-output analysis based on scenario-specific final demand, technical coefficients and per unit impacts gives us the total impacts of the French households final consumption. Assumptions are summarized in Table 3.

Results

We first present the results and secondly, we run a comparative static analysis in order to determine the hypotheses leading to the most significant environmental impact reductions. Finally, some matrix algebra gives us hints about the reliability of the results.

SCENARIO ANALYSIS

First, GHG emissions in the ambitious scenario are 18 % lower than in the reference scenario. Compared to 2007, it is a 17 % reduction (or 25 % per capita). These reductions are mainly due to efforts on energy products (71 % of the decrease), food products (8 %), and car industry (6 %). Figure 3 illustrates the results as far as GHG emissions are concerned.

Where:

- 2030-Ref stands for the "reference scenario.
- 2030-ADEME stands for the "Alleviated environmental impact" scenario.

Second, given the importance of energy efficiency and carbon cuts in our scenarios, air acidification and photochemical ox-

Table 3. Summary of simulated assumptions.

			Scenario	
			Reference	**Ambitious**
Macro		Population	+11 %	
		Income/cap	+26 %	
Final consumption	Housing (04)	Energy (heating)	-13 %	-42 %
		Electricity	+40 %	-22 %
		New dwellings	0 %	
	Transport (07)	Energy (MJ/pkm)	-13 %	-42 %
		New cars (/pers)	0 %	-19 %
	Food (01&02)	Food waste (t/cap)	-10 %	-60 %
		Dining out	+40 %	
	Equipment	Life-cycle	0 %	+20 %
		Products overdosing	+10 %	-20 %
Intermediate consumption	Energy (tep/unit)	Agriculture	0 %	+20 %
		Manufacturing industry	+10 %	-20 %
		Services	0 %	-30 %
	Steel	Car industry (t/car)	0 %	-10 %
	Timber	Construction (t/dwelling)	+5 %	+10 %
Per-unit impacts	Agriculture	CH_4 and N_20 per unit (t/t)	-5 %	-15 %
	Power generation	Carbon emissions (CO_2/kWh)	0 %	-67 %
	Foreign production (Ger.)	CO_2/unit	0 %	-29 %

Note that German power generation per-unit CO_2 emissions are assumed to decrease according to the 2030 the European climate target (i.e., a 40 % decrease in territorial emissions in 2030 compared to 1990).

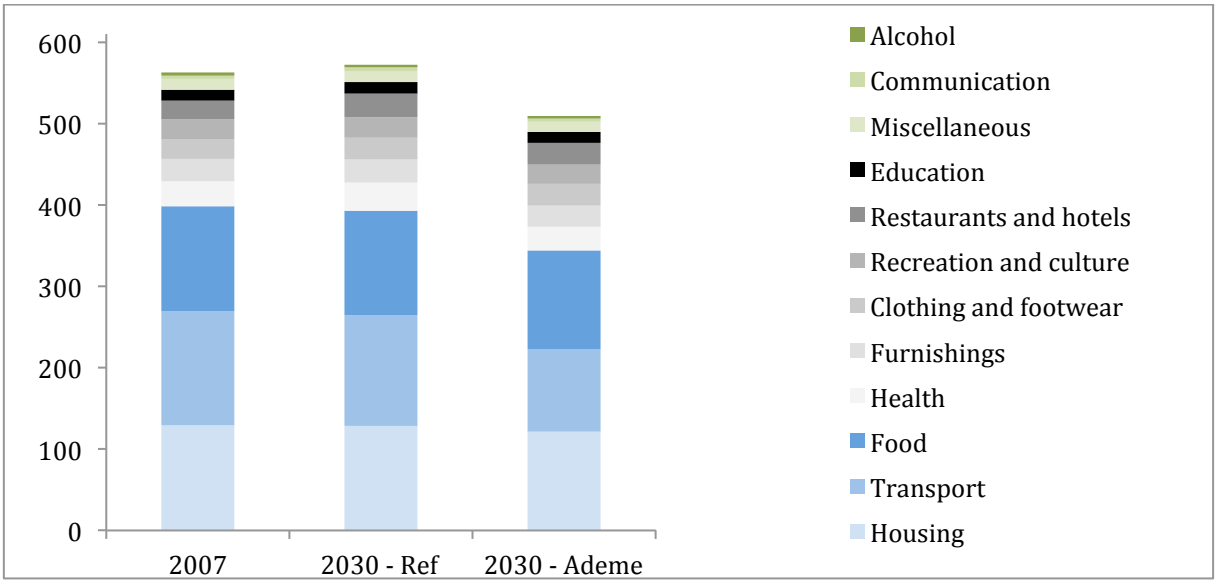

Figure 3. GHG emissions by consumption purpose, MtCO2eq. Source: Author's computations.

idation decrease only by 1 % and 3 % respectively in the ambitious scenario compared to the reference scenario, while non-dangerous industrial wastes increase by 5 %, mainly due to the increased retrofitting of buildings. Third, as about half of the emissions are embedded in imported products, the assumptions made on technical coefficients and unitary impacts in the French production system have but limited effects, and assumptions on the final consumption and direct emissions have more tangible effects. Finally, the impacts of each product have different origins: some products exhibit high unitary impacts (e.g., motor fuels, natural gas) whereas other products account for an important share of the total spending (e.g., buildings, health, education). The main results of the simulations are summarized in the Table 4.

The main conclusion to be drawn is the following one. From an environmental point-of-view, the situation is better in the ambitious scenario relative to the reference one. Indeed, significant reductions are achieved in GHG emissions, slight decrease in ACD and PCO, and a 5 % increase in non-dangerous industrial wastes. However, very ambitious targets such as 1:6 tCO_2/capita in 2050 remain far from our 2030 estimate (i.e., 6:6 tCO_2/capita) and will require important additional efforts, yet to be determined. This is all the more so as almost-immaterial growth scenarios were simulated. The good news is that there exists significant room for almost zero-cost actions possibly reducing significantly environmental impacts, such as car-sharing. The next section deals with this issue in more details.

COMPARATIVE STATIC ANALYSIS

The comparative static analysis leads us to the following conclusions. First, environmental impacts are extremely sensitive to budgetary coefficients. If overlooked by environmental policy makers, potential significant rebound-effects are to be expected. Indeed, a reduction in final consumption of a given product does not, as total spending is fixed, necessarily imply a decrease in environmental impacts. It all depends on the way spared money is then spent: according to whether households choose to spend their spared money, carbon emissions variation ranges from -1.4 % (recreational services) to +6.6 % (air transport services) relative to the ambitious scenario. Second, there exist some almost zero-cost actions that may help decrease environmental impacts. For example, technically speaking, car-sharing more intensively requires almost nothing more than some easy-to-get information and can avoid a significant amount of emissions (3 % with a 50 % increase in car occupation rate). Finally, if per-unit environmental impacts were the same as France's, carbon emissions could be further decreased by another 10 %. This latter result, given as an illustration, is yet not to be taken for granted. Indeed, international trade precisely exists because there is no such thing as a country which produces all the goods. Therefore, this estimate is clearly an upper-bound, and a deep analysis of the homogeneity of products is crucially needed.

Conclusion

Concerning the global-warming potential, the main scenario evaluates the impact of the French households' consumption in 2030 at 6.6 tCO_{2e} per capita. It is a significant reduction compared to 2007 (about -30 %). Yet, this remains far above 1.6 tCO_{2e} per capita, which corresponds to the average individual quota with a global 15 Gt CO_{2e} carbon- recycling capacity shared among 9 billion people in 2050. In any case, it has to be highlighted that without a shift from an economy of "quantity" to an economy of "quality", such limited results wouldn't even be observed. Moreover such results won't be obtained by appealing to the sole consumers' responsibility: modifications in production patterns, in institutions and territories 'organization are essential to allow for changes in our way of life.

On the other hand, important reductions of potential impacts are to be expected from both changes in the structure of the economy, as well as from the environmentally sustainable versions of new forms of exchange such as collaborative or functional economies. Both are hardly taken into account in this study. Furthermore, serious data availability issues concerning low-income trading-partner economies might lead to underestimate the impacts. Finally, in order to point at cumulative emissions effectively, trajectories issues would need to be addressed. This is a further research path.

Table 4. Environmental impacts relative to the reference scenario.

Impact	Relative variation
GHG	-18 %
ACD	-1 %
PCO	-3 %
NDIW	+5 %

Source: Authors' computations.

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