RENAULT KADJAR - 2015

- LIFE CYCLE ASSESSMENT RESULTS
- RENAULT LCA METHODOLOGY

DRIVE THE CHANGE

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A. NEW RENAULT KADJAR – LCA RESULTS

This part presents the results of the life cycle assessment of the new Renault KADJAR.
It is a comparative LCA study and compares the new Renault KADJAR with an existed model in the range. The closest one is the Renault SCENIC 3 (short, 5 passengers).

We have to precise that this comparison doesn't followed exactly the methodology mentioned in the second part of this report. Indeed, we are not comparing a replaced vehicle and the new one because Kadjar is a new car in the Renault range. The comparison is based on the customer targeted by the vehicle. KADJAR and SCENIC share the same target in term of customers (family, young people) and propose the same kind of performances (weight, habitability, number of passengers) despite their opposite design. To reinforce the comparison, we use the same engine for both. Moreover, journalists and customers consider the crossover as the best alternative to small monospace like the short SCENIC.

For all these reasons we consider the comparison with SCENIC as a good way to evaluate the environmental performances of new Renault KADJAR.Nevertheless, the results will be lower than a comparison with an older vehicle which was developed as long ago.

I GOAL AND SCOPE OF THE KADJAR STUDY

For all Renault studies, the goal and scope and the global guidelines of the LCA analysis are the same and are described precisely in the methodological part of this report (from page 19, part B).

Functional unit and vehicles assessed

The functional unit for this study is the same as for other Renault studies. It is defined as the transportation of persons in a vehicle, for a total distance of 150 000 km, during 10 years, in compliance with type approval regulation over New European Drinving Cycle.
It is described precisely in the methodological part (page 20).

The two vehicles assessed have standard equipment and similar characteristics that are described in the following table:

		SCENIC	KADJAR
General description	Constructor	RENAULT	RENAULT
	Denomination	Scenic	Kadjar
	Production Start	2009	2015
	Category	VP – M1	VP – M1
	Body	J segment	I segment
Mechanical specification	Fuel	diesel	diesel
	Engine	K9K	K9K
	Gearbox	BVM	BVM
	Max speed	180	182
	Emission standard for type approval (70/220/CEE)	EURO 5	EURO 6
	Consumption (NEDC)	4,1 L/100km	3,8 L/100km
Dimension	Length	4372	4449
	Width	1845	1836
	Height	1683	1604
Emissions	CO2 (NEDC)	105 g/km	99 g/km
	CO (NEDC)	189,6 mg/km	143,2 mg/km
	HC (NEDC)	34,1 mg/km	38 mg/km
	NOx (NEDC	44,2 mg/km	53,6 mg/km

Table 1 : Characteristics of the two vehicles compared: KADJAR and SCENIC

For information, the emission limits according EURO 5b and EURO 6 (category M1) for particular vehicles equipped with diesel engines are given in the following table:

	EURO 5b	EURO 6
CO (g/km)	0,500	0,500
HC (g/km)	0,100	0,100
NMHC (g/km)	0,230	0,170
NOx (g/km)	0,180	0,080
Part. Mass (mg/km)	5	5
Part. Number (#/km)	$6x10^{11}$	$6x10^{11}$

Table 2 : Emission limits according to EURO 5b and EURO 6 regulations

All details about emissions regulations are available in appendix VI.3.

II LIFE CYCLE INVENTORY

II.1 MATERIAL COMPOSITION

The following table shows the different materials composition of the 2 compared vehicles:

	SCENIC 3	KADJAR
Material categories	***Total mass (kg)***	***Total mass (kg)***
1 - Metals	1269,2	1029,7
2 - Polymers	253,8	220,0
3 - Elastomers	65,7	47,3
4 – Glass and ceramic	54,8	38,9
5 - Fluids	77,8	69,8
6 – Organic material	9,5	4,7
7 - Others	4,7	3,6
TOTAL	**1735**	**1414**

Table 3 : Material description for KADJAR & SCENIC

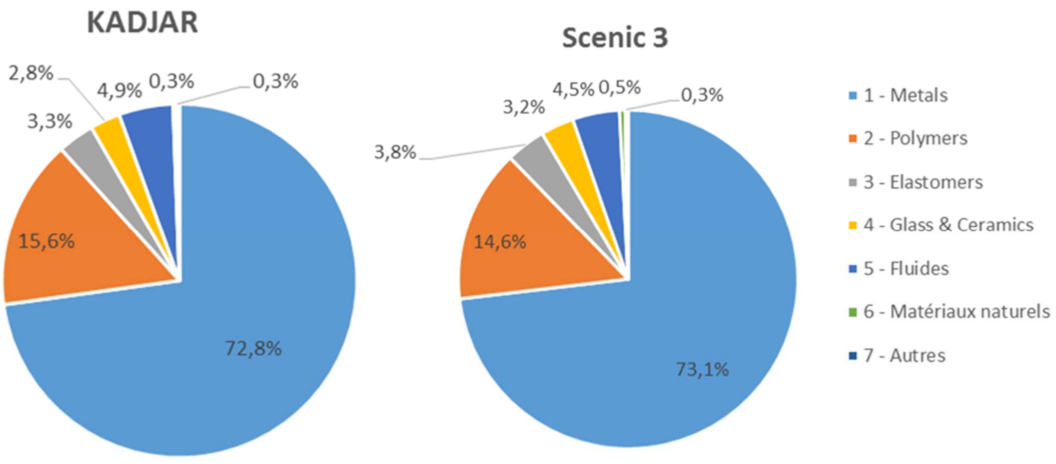


Figure 1 : Material distribution of SCENIC 3 & KADJAR

As described in the graphs, the distribution of the materials is almost the same between the vehicles.

These materials compisitions allow us to conclude that KADJAR and SCENIC have the same positioning in the range.

Although both vehicle have the same ratios, KADJAR is lighter than Scenic thanks to its new platform and the work achieved to reduce the global weight of the vehicle. This achievement is linked to a global roadmap in order to reduce the weight of our vehicle.

II.2 PLANTS AND LOGISTICS

The two vehicles are not assembled in the same factory, one is assembled in France and the second one in Spain.
Table 4 shows also where engine and gearbox for both vehcile are manufactured.

	Scenic	**Kadjar**
Vehicle assembly factory	Douai (FRANCE)	Palencia (SPAIN)
Engine factory	Valladolid (SPAIN)	Valladolid (SPAIN)
Gearbox factory	Cacia (PORTUGAL)	Seville (SPAIN)

Table 4 : Production plants localization

The emissions and consumptions related to the vehicle assembly, engine and gearbox are taken into account.
Logistic is also estimated according to those data.

III RESULTS OF THE LIFE CYCLE IMPACT ASSESSMENT

III.1 NEW KADJAR

Figure 2 presents the distribution of selected impacts all along the life cycle.
Concerning the recycling phase, it is modelled according to reference scenario (see chapter III.6, p30).

Concerning the presentation of the results:

- Vehicle production includes raw material extraction and manufacturing, the production of parts and the assembly of the vehicle. It also includes logistics from first rank supplier to factory and to final customer.
- The use phase includes the production of fuel and the use of the vehicle all along its life cycle (as defined in the functional unit). It also includes the maintenance during the life cycle
- The end of life includes the different processes to dismantle and shred the end of life vehicle, also the recycling processes of the different specific parts of the car.

Associated data is gathered in Table 5.

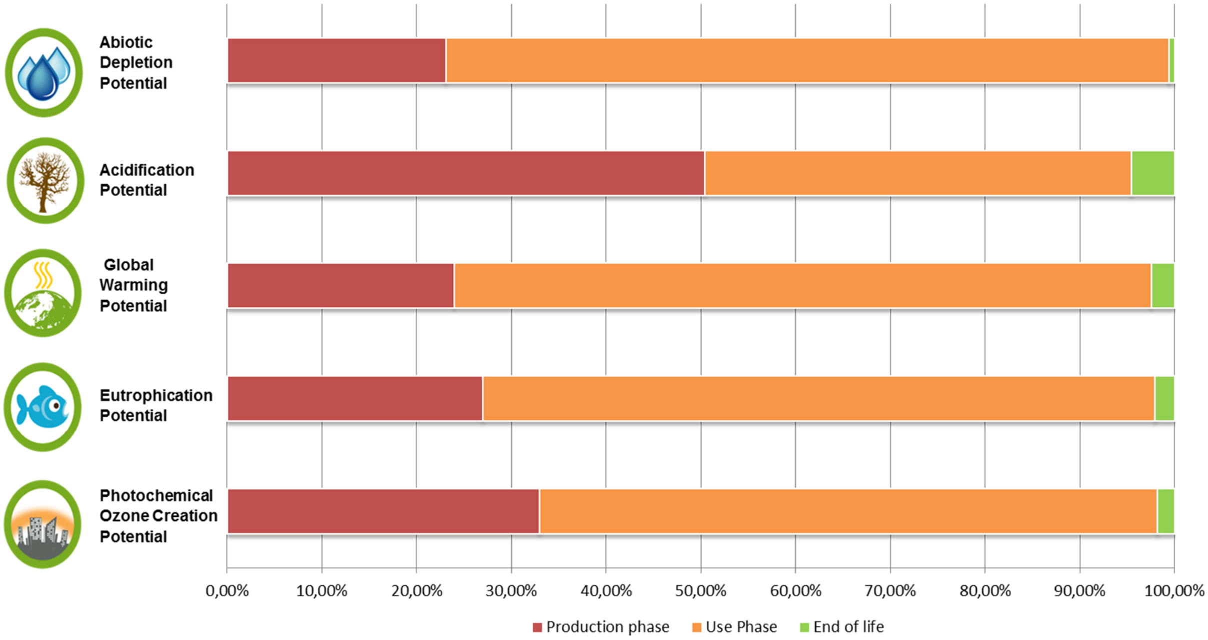


Figure 2 : Repartition of environmental impact of KADJAR along its life cycle

	QUANTITY	PART IN LIFE CYCLE
ADP fossil: Abiotic depletion Potential (fossil) [MJ]		
Vehicle Production	72824,68	23,10%
Use Phase	240982,99	76,34%
End of life	1773,23	0,56%
AP: Acidification Potential [kg SO2-Equiv.]		
Vehicle Production	25,67	50,40%
Use Phase	22,97	46,09%
End of life	2,30	4,51%
GWP: Global Warming Potential 100 years [kg CO2-Equiv.]		
Vehicle Production	5550,86	24,00%
Use Phase	17009,70	73,53%
End of life	572,55	2,48%
EP: Eutrophication Potential [kg Phosphate-Equiv.]		
Vehicle Production	2,13	26,97%
Use Phase	5,60	70,99%
End of life	0,16	2,04%
POCP: Photochemical Ozone Creation Potential [kg Ethene-Equiv.]		
Vehicle Production	2,75	32,93%
Use Phase	5,45	65,24%
End of life	0,15	1,83%

Table 5 : Environmental impact of the new KADJAR and repartition

For more information about the choice of indicators, refer to the methodological part, chapter IV.1, p 33.

As explained on the methodological part, we have chosen to give results for 2 recycling scenario. The following figure gives the results for scenario 2 (recycling credits are estimated and included in the recycling phase results).

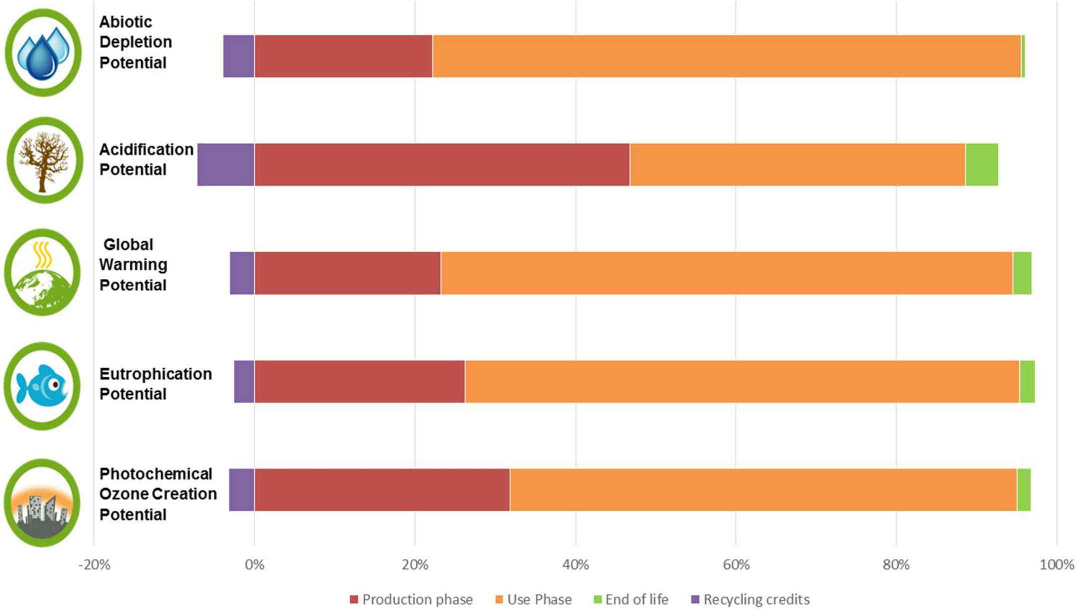


Figure 3 : Repartition of environmental impacts of the new KADJAR along its life cycle, according to the recycling scenario with recycling credits

	QUANTITY	PART IN LIFE CYCLE
	ADP fossil: Abiotic depletion Potential (fossil) [MJ]	
Vehicle Production	72824,68	24,09%
Use Phase	240982,99	79,61%
End of life	1773,23	0,59%
Recycling credits	-12948,71	-4,28%
	AP: Acidification Potential [kg SO2-Equiv.]	
Vehicle Production	25,67	54,63%
Use Phase	22,97	48,87%
End of life	2,30	4,89%
Recycling credits	-3,94	-8,39%
	GWP: Global Warming Potential 100 years [kg CO2-Equiv.]	
Vehicle Production	5550,86	24,79%
Use Phase	17009,70	75,96%
End of life	572,55	2,56%
Recycling credits	-739,57	-3,30%
	EP: Eutrophication Potential [kg Phosphate-Equiv.]	
Vehicle Production	2,13	27,72%
Use Phase	5,60	72,97%
End of life	0,16	2,10%
Recycling credits	-0,21	-2,78%
	POCP: Photochemical Ozone Creation Potential [kg Ethene-Equiv.]	
Vehicle Production	2,75	34,07%
Use Phase	5,45	67,49%
End of life	0,15	1,90%
Recycling credits	-0,28	-3,45%

Table 6 : Environmental impact of the new KADJAR according the recycling scenario including recycling credits

III.2 COMPARISON BETWEEN SCENIC 3 AND KADJAR

The following figure shows the comparison between the two vehicles.

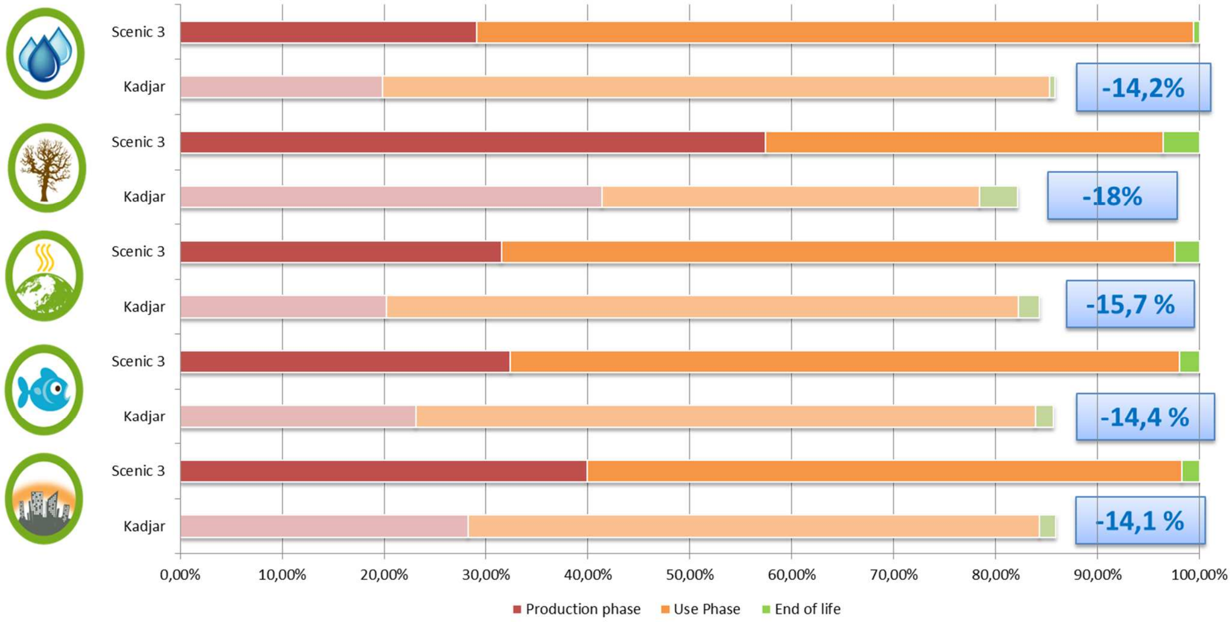


Figure 4 : Comparison between SCENIC 3 & KADJAR for the selected impacts

The difference between SCENIC 3 and KADJAR is comprised for each environmental impact between 14 and 18%.

The main difference for each impact concerns the production; the differences are relatively low compared to other vehicles in the Renault range. We can explain this results by the choice of a new version of SCENIC 3 equiped with a EURO 5b engine which is already respectful of the environment. Nevertheless, we used the same LCA model, with the same hypothesis in order to minimize the incertainties. In this situation, we can notice the significative improvement obtained by the new ways of development applied on Kadjar. The weight reduction, and the use of a new platform have allowed to decrease the global impact of the car.

This comparison highlights the difficulties to decrease on each vehicle its environmental impacts.

III.3 RESULTS ANALYSIS

Before the results explanations, we can notice below some details about the cut-offs application:

Regarding the non-reassembled flows:

The table below shows that cutoffs on vehicle mass are lower than 1%.

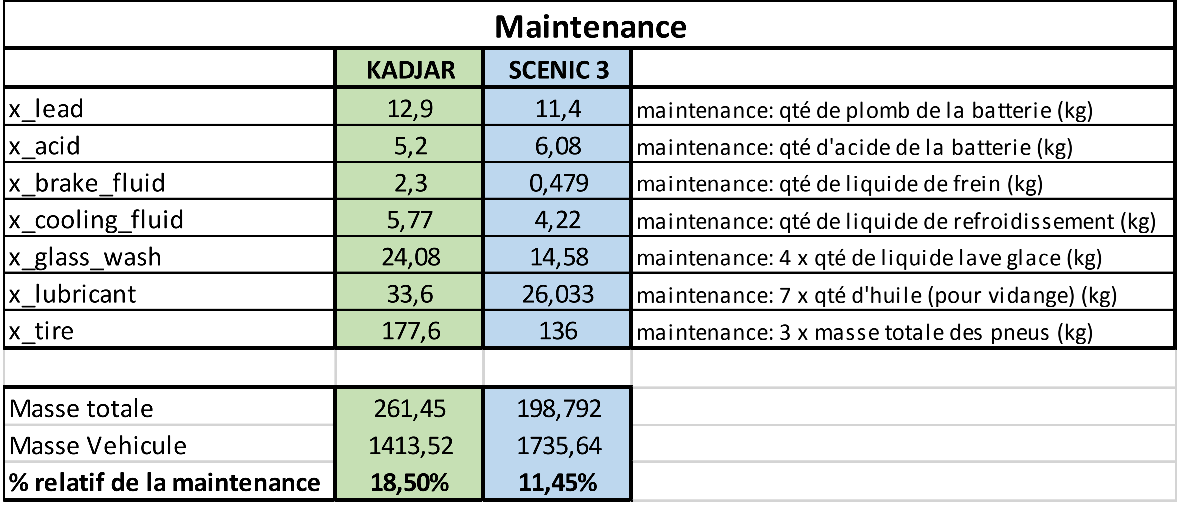
Cut off criteria ESPACE		
	SCENIC	**KADJAR**
Total mass cut off (kg)	10,24	1,01
Cut off %	0,59%	0,07%

The performance in term of cut-off comes from our better knowledge of material composition. We reached on KADJAR a high level of knowledge thanks to our system of material data sheet collection. Indeed, compared to Scenic 3, we have a reached a high level of MDS documentation

(>95%) thanks to a new way of management and a favorable panel of suppliers. Furthermore, we have to apply the same kind of datas management in our ongoing project.

Regarding the spare parts:

For the moment, we don’t take into account all the spare parts. We are thinking about a modification of our processes. Nevertheless, we have noticed below the mass of spare parts regarding the total weight of the vehicle. We have to keep in mind our goal which is making a comparison between 2 vehicles with the same hypothesis in term of spare parts used.



Maintenance

	KADJAR	SCENIC 3	
x_lead	12,9	11,4	maintenance: qté de plomb de la batterie (kg)
x_acid	5,2	6,08	maintenance: qté d'acide de la batterie (kg)
x_brake_fluid	2,3	0,479	maintenance: qté de liquide de frein (kg)
x_cooling_fluid	5,77	4,22	maintenance: qté de liquide de refroidissement (kg)
x_glass_wash	24,08	14,58	maintenance: 4 x qté de liquide lave glace (kg)
x_lubricant	33,6	26,033	maintenance: 7 x qté d'huile (pour vidange) (kg)
x_tire	177,6	136	maintenance: 3 x masse totale des pneus (kg)
Masse totale	261,45	198,792	
Masse Vehicule	1413,52	1735,64	
% relatif de la maintenance	**18,50%**	**11,45%**	

Regarding the manufacturing scraps:

For the moment, we don’t take into account the scraps coming from plants. As the spare parts, we are thinking about a modification of our processes.

Concerning the full LCA of cars, we can notice that the main contribution comes from the use phase.

The results analysis shows the details of the contributions of each phase of the vehicle life cycle.

Vehicle production:

The following figure shows the different contributions for vehicle production.

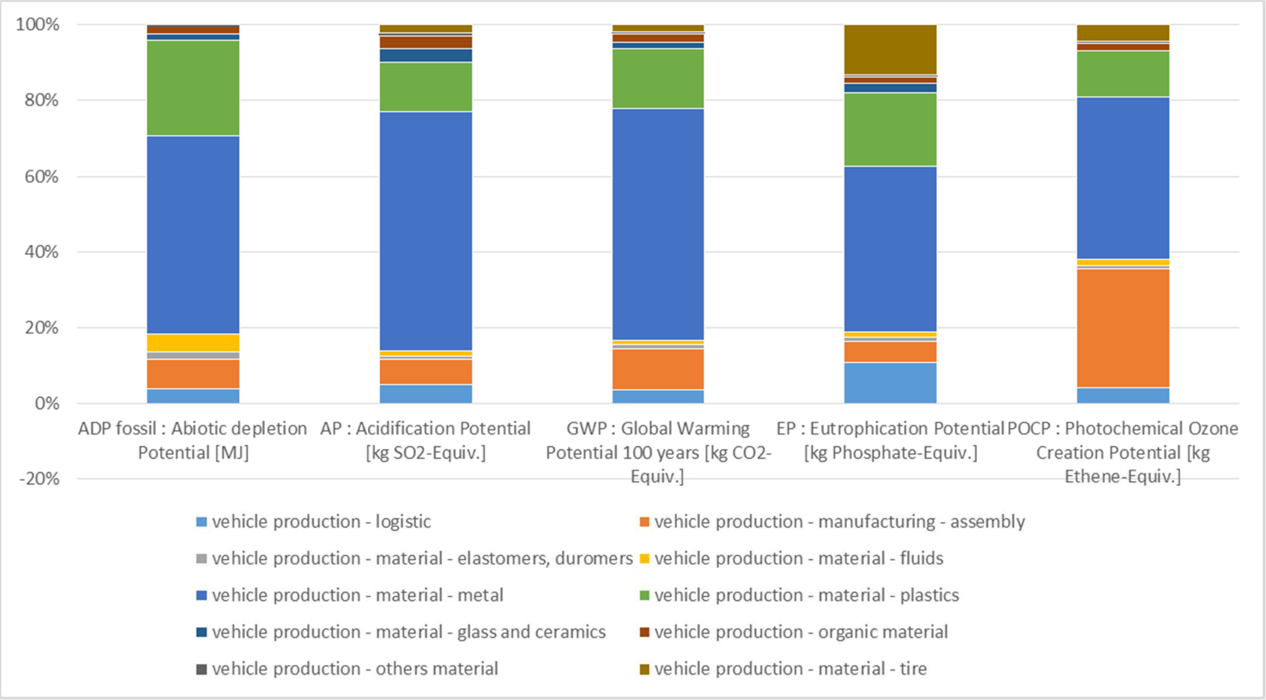


Figure 5 : Contributions for vehicle production KADJAR

First of all, the contribution of materials is preponderant in the production phase. Logistics and manufacturing represent less than 20% of the impacts excepting for POCP for which assembly and logistis represent around 40%.

Within materials, metal and plastics are responsible for more than 80% of the impacts excepting for eutrophication and POCP wherein the production of tire and the assembly are significant. However, we notice that manufacturing is mainly impacted for POCP (around 30%) which representative the major impact of manufacturing.

The main contributors identified are the cast aluminimum, and steel cast used for body parts for metals.

Use phase:

The following figure presents results for the different contributions of the use phase.

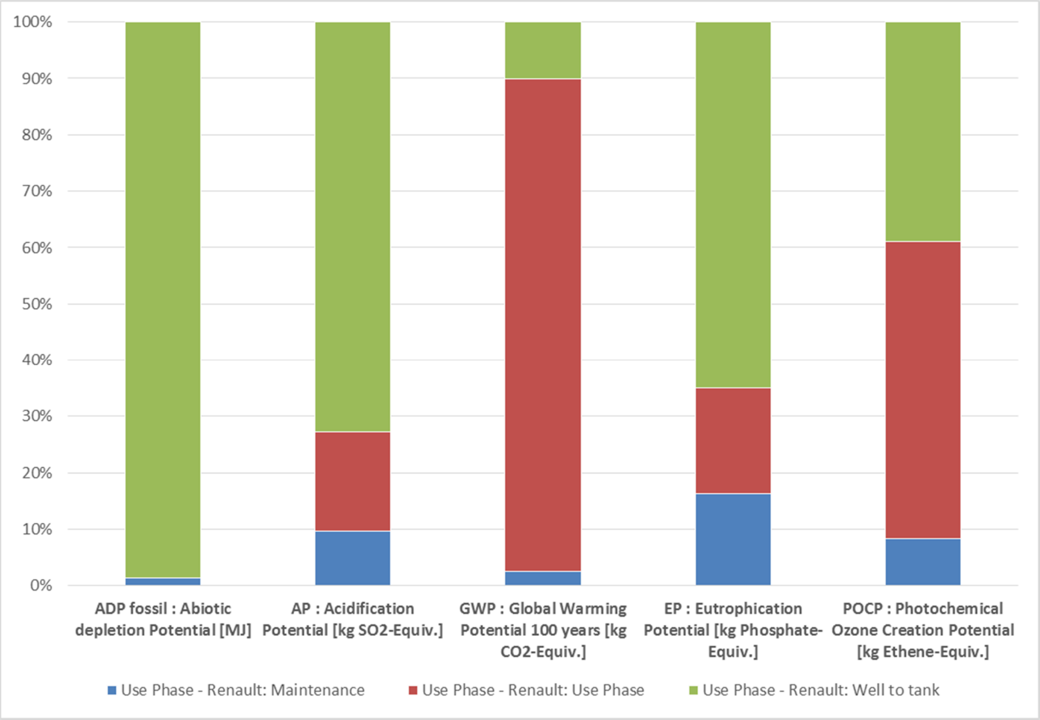


Figure 6 : Contributions for use phase KADJAR

For the use phase, contributions are closely linked to different indicators, but the production of fuel is the most significant for all the impact (between 40% and up to more than 95% for ADP) excepting for the global warming which is composed mainly with the driving phase.
If we consider the driving phase of the vehicle (well to tank + tank to wheel), it represents more than 80% of the impacts.

End of life:

The following figure presents the contributions of end of life for each environmental impact.

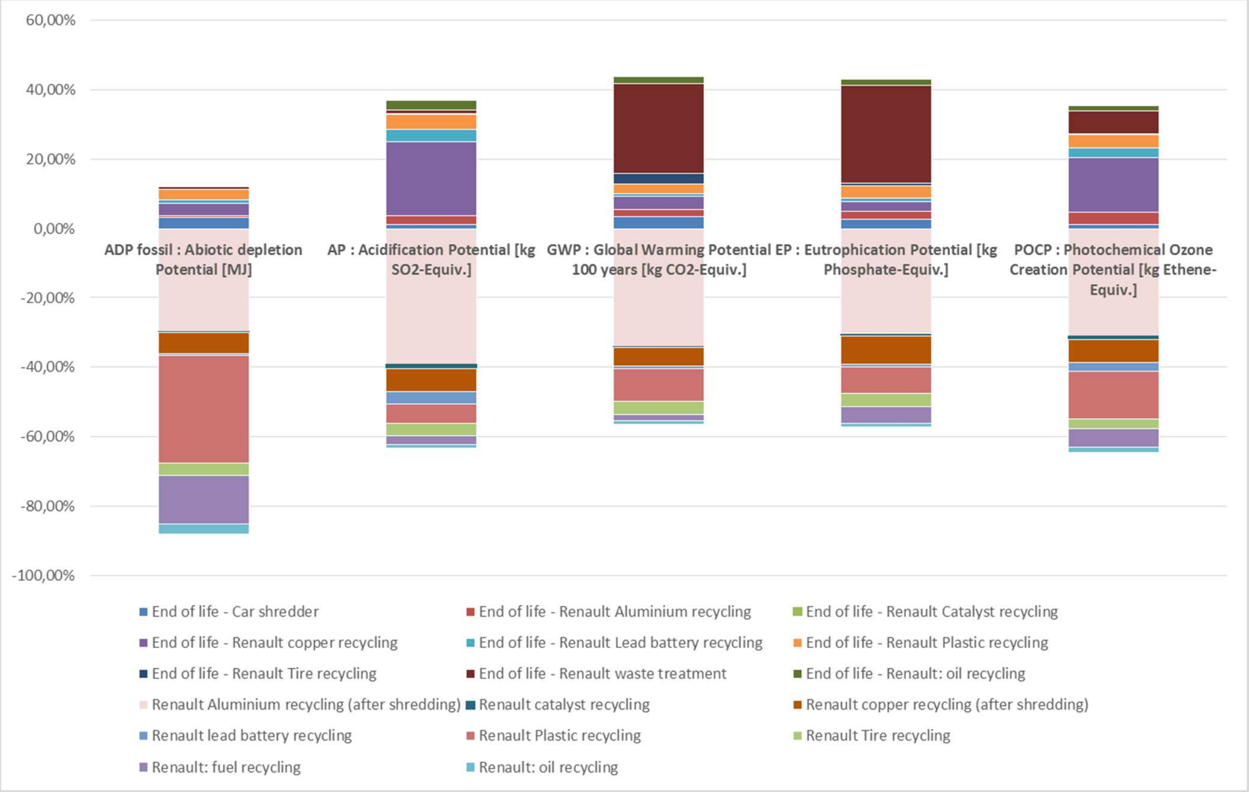


Figure 7: contributions for end of life KADJAR

Distribution of impact is specific for each type of recycling and associated credits.
The main contributions are for copper recycling ang waste treatment. These two contributors are responsible of more than 25% of the impacts for each impact.
For recycling credits, the main benefits come from the aluminium and plastics recycling. Despite the benefits, the process of plastics recycling is the third contributors in term of impact.

III.4 NORMALIZATION OF THE RESULTS

In order to give another interpretation of the results, it is possible to normalize the several potential impacts presented in this study.
Normalization consists in dividing the value of the product per the value of a reference case on each indicator.
This tool gives the contribution of the studied product on the chosen indicators.
The normalization methodology is CML2001 Western Europe, which is in line with our scope.
Normalization factors are available thanks to our GaBi software and Thinkstep database. They are gathered in the following table:

CML2001 - Apr. 2013, Western Europe (EU)		
Abiotic Depletion (ADP fossil)	3,06202 x 10^{13}	MJ
Acidification Potential (AP)	27354100000	kg SO2-Equiv.
Global Warming Potential (GWP 100 years)	4,8832 x 10^{12}	kg CO2-Equiv.
Eutrophication Potential (EP)	12821957276	kg Phosphate-Equiv.
Photochem. Ozone Creation Potential (POCP)	8241462011	kg Ethene-Equiv.

The results are presented below.

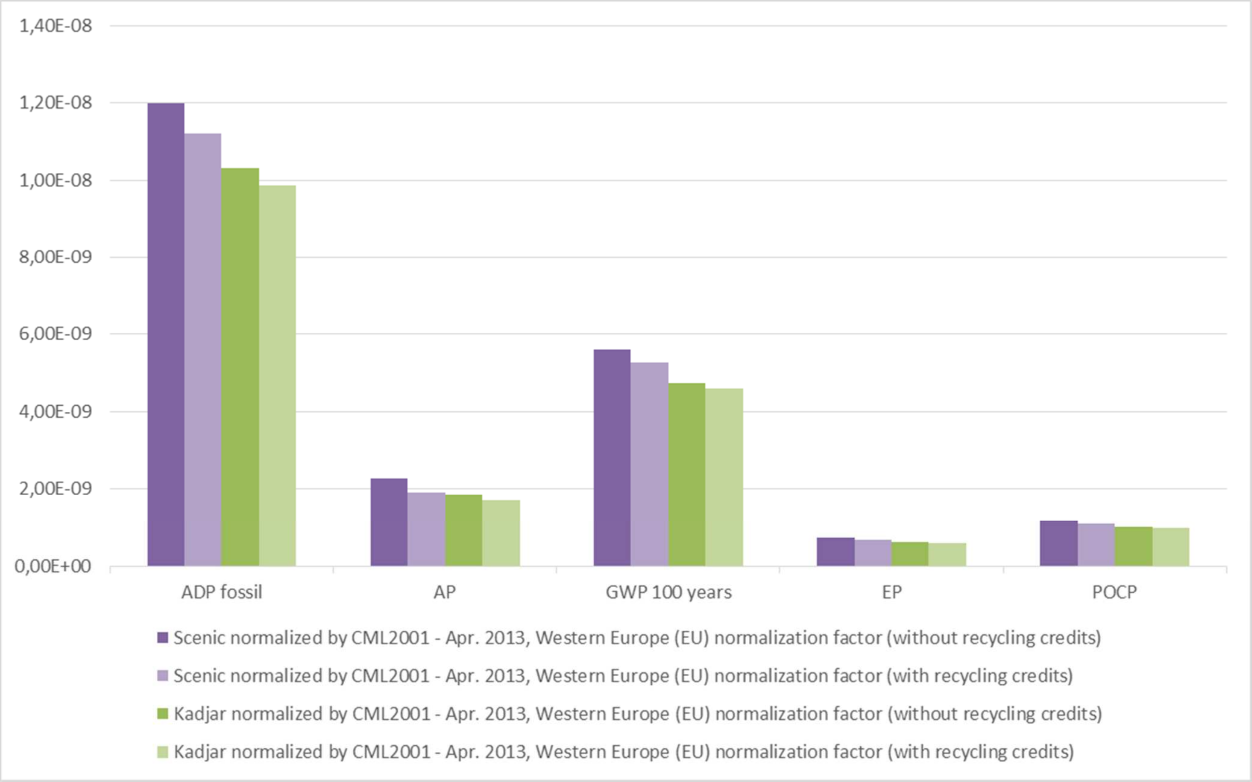


Figure 8 : Normalized results for SCENIC 3 and KADJAR

From this normalization, we can see that eutrophication burden is the lowest vehicle contribution for European emissions.

Concerning abiotic depletion potential, the vehicles' contribution comes from the large use of fossil resources for fuel production.

The figure highlights improvements between the two vehicles on all environmental burdens but also the positive contribution of recycling mainly on the first three impacts.

IV CONCLUSIONS AND LIMITS

We performed in this report a comparison between KADJAR & SCENIC 3 to identify the differences in term of environmental impact by using LCA.

We have defined 5 impacts to measure and compare our vehicles, and the analysis of each of them show us an improvement on KADJAR compared to SCENIC 3.

We can conclude (based on the following hypothesis which allow to make the comparisons) that KADJAR has a lower environmental footprint than SCENIC despite they are both recent:

- Same market and target in term of customers despite the design modifications.
- Same vehicle range.
- Same engines and equipments.
- Same perimeters of comparison with the same use cases.
- ➔ Earnings are directly linked to the vehicle and due to its improvement in term of CO2 emissions, materials using, supply chain management.

However, we have to mention some limits for the vehicle study.

- The comparison with SCENIC 3 launched in 2009 but updated in 2014 shows an improvement in term of environmental footprint. Despite a very close target in term of customer and application we have to mention that we are in the limit of the methodology. Nevertheless, the improvements are directly linked to the new ways of development.

In general for the LCA performance at Renault, we have identify some ways of improvement:

- We will sudy the possibility to include all the waste (manufacturing and maintenance which represents the main contribution to the global waste.).
- We have planned an updated of the oldest Databases with our supplier.
- We use for the moment only 5 impacts contrary to JRC. On this point, we won't make any modification.
- We don't take into account the contribution of the plants in term of building, but we are perfroming an update concerning the datas, and the values will be integrated in the future analysis.

We are continually improving our approach of the LCA analysis at Renault to include all the new developments and the remarks coming from experts of Solinnen.

B. RENAULT LCA METHODOLOGY

This part of the document presents the framework to conduct the Life Cycle Assessment studies of Renault vehicles.
This methodology is the same for all vehicle studies.
This methodology report is the version v1.

I INTRODUCTION / CONTEXT

Based on ISO 14040-44 standards, Life Cycle Assessment is a technique to assess in a scientific and objective way, all potential environmental impacts of a product, considering its whole life cycle: from cradle to grave as described in Figure 9.

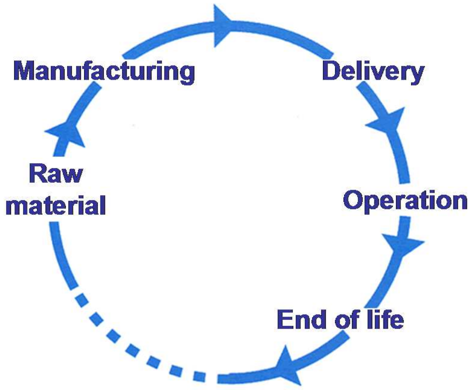


Figure 9 : Life cycle of a product

LCA studies comply with the ISO 14040 and 14044 standards [ISO 2006], and the following framework shows how to conduct LCA studies.
Generally Renault LCA studies compare the results for a vehicle launched with the predecessor vehicle.

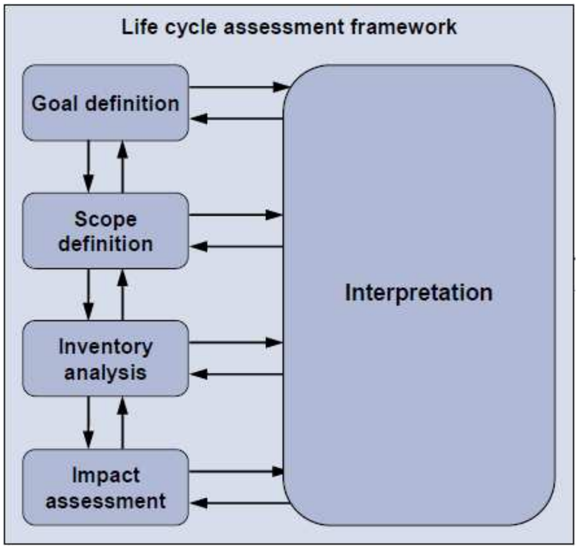


Figure 10 : Schematic table of LCA steps [EC 2010a]

Context: Who, why?

Goal and scope definition: Scope of the study and its context (temporal, geographic and technological)

Inventory analysis: Identify and quantify the system's incoming and outgoing flows. Identify errors from this step.

Impacts assessment: Transcription of flows in potential environmental impact.

Interpretation: Summary of environmental records and their use to achieve considered goals

II GOALS AND SCOPE OF RENAULT'S LCA STUDIES

II.1 GOALS OF RENAULT'S LCA STUDIES

The goal of Renault's LCA studies is to assess the environmental impacts of all new vehicles. When it exists, the goal of LCA studies is to compare the new vehicle with its predecessor.

The goal of the study is precisely detailed through six aspects:
- Intended application(s) and decision context
- Limitations
- Targeted audience
- Comparative studies to be disclosed to the public
- Commissioner of the study and other influential actors

II.1.1 INTENDED APPLICATIONS AND DECISION CONTEXT

LCA create new opportunities for the Group's strategy to diverse dialogues with stakeholders, thus improving the knowledge of the environmental impacts of Renault products.
This methodology report describes the global framework and Life Cycle Inventory data sets to be used in Renault's calculation model. The methodology report is common for all vehicles studies.
The life cycle is modelled by depicting the existing supply-chain attributionally. Primary physical data will be collected and associated to generic processes.

II.1.2 LIMITATIONS

An LCA study is an image of the product as it is launched and operates for defined time and mileage, as described in the functional unit (II.2.1).
A 10 year and 150 000 kilometers in the New European Driving Cycle (NEDC) standard is usually applied in Renault studies. It is a meanvalue and is not representative for all vehicles' use.However, Renault use this value in accordance with the compromise established between the CCFA and the automotive industry.
As a standard for all studies, benefits from the recycling processes, considered as potential credit, are not allocated to products. Results will be provided for information on the potential benefit for Renault.
Each LCA study is an attributional LCA and marginal or rebound effects are not taken into account.

Note: Limitations on new technologies (eg. Electric vehicle) are further detailed in relevant LCA reports.

II.1.3 TARGETED AUDIENCE

LCA studies are dedicated to the Renault internal audience and will be used as a reference by Renault management to define future environmental objectives for Renault products.
They will also provide a clear picture of the issues linked to specific parts production, and identify critical points to help engineers with ecodesign.

LCA studies will be available to expert stakeholders in order to sustain the dialogue on life cycle management and an executive summary can be prepared for non-expert readers.

An expert in environment and life cycle assessment will be assigned to review each report in compliance with the ISO 14040 standard and to validate the findings. The LCA critical review report is available with each LCA study.

II.1.4 VIGILANCE FOR PUBLIC DISCLOSURE

Studies are planned to be disclosed to the public.
It is not possible to make a direct comparison between the results of two different LCA studies, for instance from any other car manufacturer.

When a comparison is made it is described precisely in the specific vehicle study report and it usually concerns the comparison between the new vehicle and its predecessor.
The main objective is to maintain a logic when two vehicle are compared. We have to compare only 2 vehicles dedicated to the same market, with the same customer target and behavior. In the case of the new comer in the range, we will compare the new vehicle with the closest existed vehicle in the range. For example, we coul compare Kadjar and Short Scenic. They are dedicated to the same market, with the same objectives.

Thus it is also not possible to compare two different Renault vehicle studies (different model, technologies…).

II.2 GOAL & SCOPE OF THE VEHICLE STUDY

LCA reports detail and analyse the potential environmental impacts of different Renault models.
The results are calculated in compliance with the ISO 14040:2006 and 14044:2006 standards. The detailed perimeter of LCA studies and data collection is presented below. All specific information concerning the vehicle with respect to scope definition is detailed in the vehicle dedicated LCA study.
The 2 studied vehicles are compared by using the same model. The methodologicals choices are the same and we use the same mapping file. The results are calculated by using the same database and also the same version. It allows us to make sure that the vehicles are compared with the same kind of inputs and the same updated methods.

II.2.1 FUNCTIONAL UNIT AND REFERENCE FLOW

- The functional unit defines and clarifies the qualitative and quantitative aspects of the function(s) along with some essential questions: “what”, “how much”, “how well”, and “for how long”.

Functional unit

- What: Transportation of passengers in a vehicle
- How much: 150 000 km (Europe geographic scope)
- How long: 10 years
- How well: Respect of the norms, studied vehicle type approval

Definition of a general vehicle functional unit:

Transportation of persons in a vehicle, for a total distance of 150 000 kms (~93 000 miles), during 10 years, in compliance with studied vehicle type approval norms (e.g. NEDC driving cycle)

- The vehicle itself defines the reference flow. It is described precisely in the chapter “Goal and scope of the vehicle study” of the dedicated LCA study.

II.2.2 SYSTEM BOUNDARIES

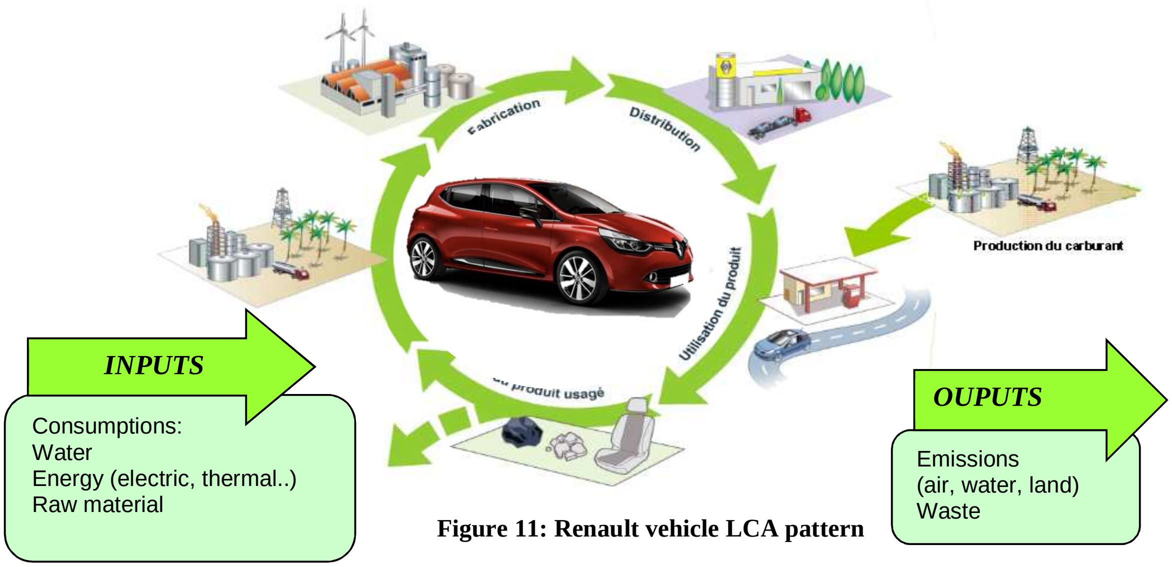


Figure 11: Renault vehicle LCA pattern

The LCA studies analyze all the necessary data to cover the 3 main steps that contribute to the life cycle impacts:

- the production of the vehicle which include materials extraction and parts production, logistic of parts and vehicle
- the use of the vehicle including also fuel production (Diesel, gasoline or electricity),
- the end of life treatment including dismantling and shredding

II.2.2.1 Cutoff criteria for initial inclusion of incoming (consumption) or outgoing (emissions)

A default cutoff criteria of 95% in mass or energy is applied on all study. In addition a criteria of 99% in mass is applied on the bill of materials of the studied vehicle and all substances of environmental signficance such as toxic substances and rare ressources shall be taken into account (as described in Figure 12). The cut-offs values are calcultated for each vehicles as it is mentioned in part III.3.
NB: Omitted flows will not include toxic substances and rare resources like platinum or gold (i.e. electronic components)
- On the use of a thermal vehicle, for example with a consumption at 4L/100km, no more than 300 L can be neglected (≈250kg) (5% of a consumption of 4L/100km on a distance of 150 000 km during 10 years is 300 L)
- For various emissions (air, water, land) calculated flows are approximated to µg/reference flow.

For more information about cutoff criteria applied to the different elements of LCA software databases used: GaBi 6.0, report to documentation available at:
http://database-documentation.gabi-software.com/

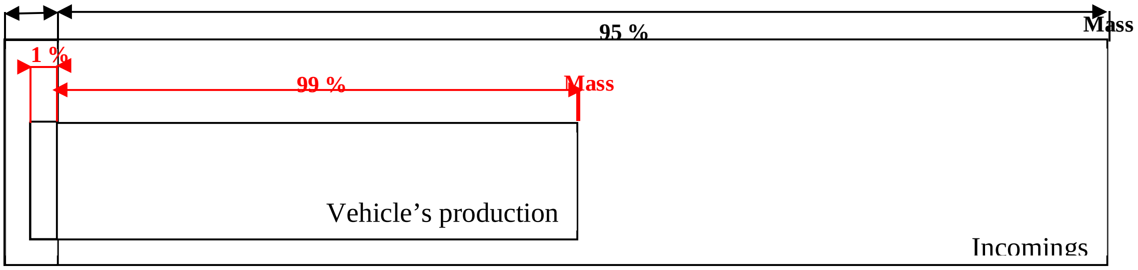


Figure 12: Cutoff criteria representation

II.2.2.2 System modeling

The construction of infrastructures like trucks, roads or other buildings is excluded as they are the same for all vehicles studied.
Concerning factories, their impact is negligible and explained in the methodological report (V.1)

Figure 13 represents steps and elements constituting the system: perimeter included in the studies and the one which is excluded such as material second life benefits or vehicle sales.

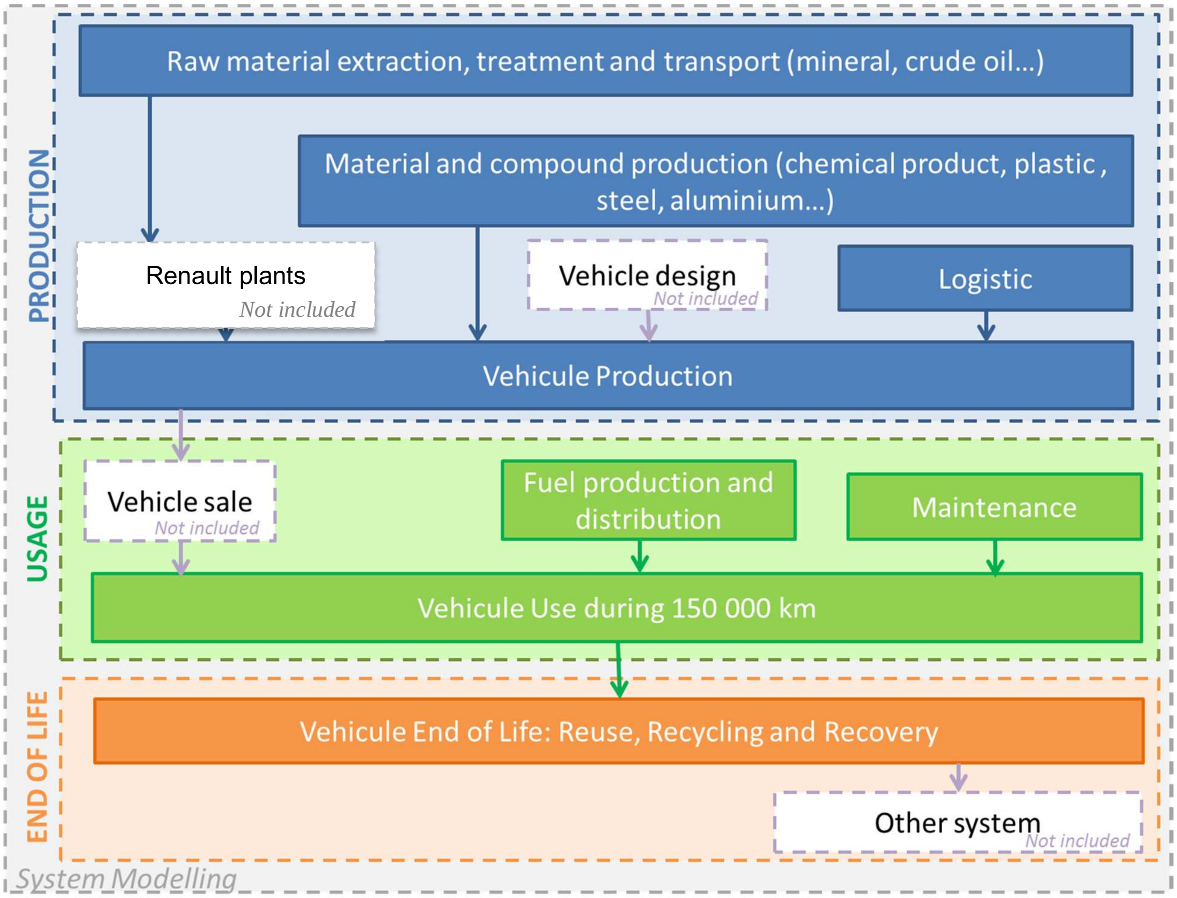


Figure 13 : Systems modeling

II.2.2.3 Production of parts and vehicles

The production phase gathers:

- The raw material extraction phase and also the production of the different Renault parts. These data are based on material information
- The assembly of the vehicle, thus including manufacturing inputs and outputs.

The identification of vehicles material content enables the estimation of the total supply chain impact from material production to processing stages.
The impact of transformation processes is proportional to the mass of material.

GaBi Thinkstep datasets are used to get the transformation impacts.It is average transformation information.

When choice is possible, the supply chain is modeled as European wide. In term of supply chain modelization, we don't take into account the supplier's localization. To apply a representative impact, we choose a value of 2000km as inbound impact by trucks.
The list of all aggregated datasets used in the Renault modelling system is available in APPENDIX VI.4.

In the case of electric vehicles studies, the battery production is treated apart and specification is described in the relevant report.

II.2.2.4 Fuel production

Fuel production corresponds to the « well to tank (WTT) » step (whole production of fuel from extraction to vehicle's tank filling)

For Diesel, gasoline or electricity, Thinkstep GaBi datatsets are considered depending on the country where the vehicle is sold (see APPENDIX VI.4).

II.2.2.5 Logistics

Logistic "inbound", which include all logistic of parts is estimated according to logistic experts in Renault. A sensitivity analysis shows that logistic inbound is not the main contribution of vehicle LCA results and that the estimation is relevant. We use a value of 2000km by trucks as inputs for logistic inbound calculation.
Logistic outbound, which include he delivery of assembled vehicles from the assembly plant to final customer is considered.

II.2.2.6 Use

The use phase, defined for 150 000 km, includes:

- Fuel consumption (gasoline, diesel, electricity)
- Atmospheric emissions from thermal engine operation and electricity production: CO_2, CO, NOx, HC, SO_2, Particles PM10 (from diesel engines)
- Maintenance detailed in chapter III.5.3 :
  - Oil (drain), oil filters (thermal engines), tires, windscreen washer liquid, air conditioning

The hypothesis use for maintenance are the same for all the vehicles.

II.2.2.7 End of life

European Commission regulated the treatment of vehicles at their end of life.
Directive 2000/53/CE (through Decree n°2003-727) de fines following regulations for January 1, 2015:

- 85% of re-use and recycling
- 95% of re-use, recycling and recovery

The end of life modelling follows these regulations.

III LIFE CYCLE INVENTORY ASSESSMENT

III.1 DATA COLLECTION: METHODS AND PROCEDURES

The Data collection phase consists in gathering all information on any parts of the vehicle (material and process) but also on the manufacture and usage of the vehicle.
Once collected, this data is used in LCA software (GaBi 6.0), in a model developed by Renault, specifically dedicated to its needs. The life cycle pattern of the vehicle is the result obtained describing all processes and flows.

Collecting data to perform LCA is complex. It requires different information from all departments, not only technical data but also marketing data, environmental reports or material and parts details.

III.2 VEHICLE DESCRIPTION

For one specific Renault vehicle, there is a large variety of models that can be explained by:

- Different levels of equipment
- Different engines

The LCA is conducted for only one model (one level of equipment, but it is possible to conduct the LCA for one gasoline vehicle and also one Diesel vehicle).
This chosen model is the one that is concerned by the environmental Renault signature Eco2 (information on Eco 2 signature is available on Renault website).

The vehicle is also identified with a VIN number, required to obtain the homologation data, necessary to calculate the use phase.

III.3 VEHICLES' COMPOSITION

III.3.1 VEHICLE MATERIAL COMPOSITION

According to regulation (Directive 2000/53/EC of the European Parliament and the council on end of life vehicles and Directive 2005/64/EC of the European Parliament and the council on type approval of motor vehicles with regard to their reusability, recyclability and recoverability), Renault has to know for each vehicle sold the exact vehicle material composition.

To comply with these regulations Renault and other car manufacturers use IMDS (International Material Data System). This system gathers the information on material concerning every parts of the vehicle (from Original Equipment Manufacturers and their suppliers) so that Renault can have the material information for the whole vehicle.

Thanks to the IMDS material database, it is possible to describe the vehicle according different material categories. We use, if it is necessary to complete the IMDS datas, the same datas use for the recycling certification according to European regulation 2000/53/EC.

These data are those that are considered to get the whole impact of raw material during the vehicle life cycle thanks to GaBi software.

III.3.2 PROCESSING STEPS – PRODUCTION OF PARTS

As no information is available on each process (stamping, water consumption, energy consumption, emissions, etc…) specific to each part, Thinkstep developed datasets to describe the main material processes (stamping, Aluminium parts, plastic injection moulding…). These datasets are used and associated to the Renault‘s vehicle material description;
The updated dates are mentioned in part VI.4.

In order to carry out the LCA calculation, the vehicle material and processing steps are described thanks to the BOM import functonnality which has been developed specifically for Renault‘s needs.

The GaBi datasets can be country specific. When the choice is possible, we prefer:

1- European datasets
2- Global dataset (world meanvalue)

3- If the choice is possible for different countries but there is no European or worldwide datasets, we choose preferably Germany which presents an interesting and representative electrical mix.

The list of all the datasets used in the vehicle model is available in APPENDIX VI.4.
Bom import is a specific tool developed by Thinkstep for Renault. This software allows to define a relationship between the materials used in Renault's cars (coming from IMDS) and the specific flows defined in GaBi. The mapping uses for our LCA studies is already updated by the new analysis.

The figure mentions below as for goal to explain how our datas are collected.

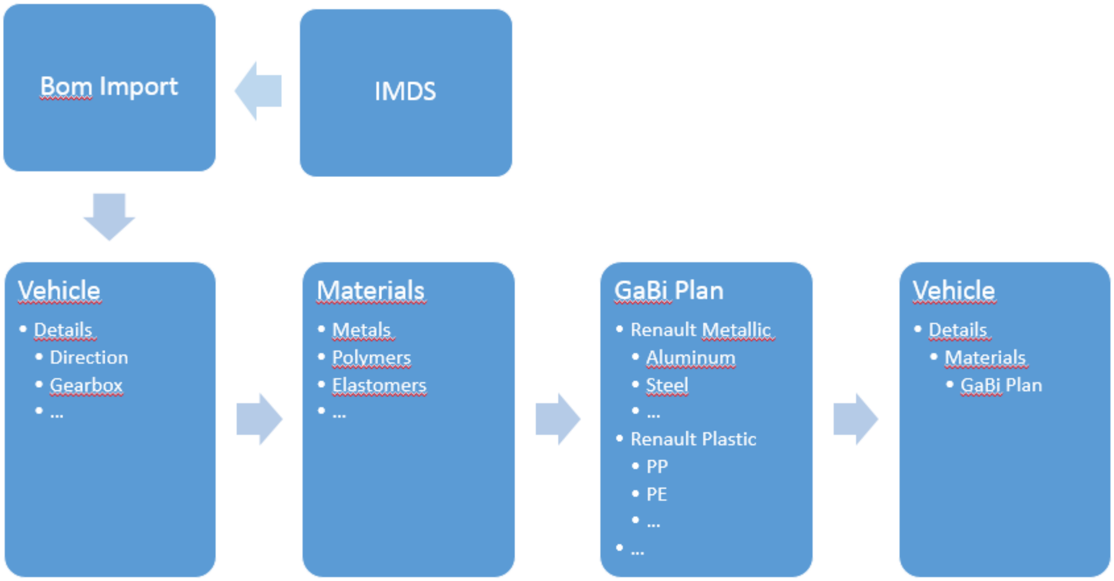


Figure 14 : Bom Import

A mapping file links a set of processes (called Gabi plan) to each material or component. Therefore, each vehicle is fully modelled by its list of components and material (provided by the IMDS database via the BOM import software) and the associated plans (linked with the GaBi mapping tool).

III.4 **FACTORIES AND LOGISTIC**

III.4.1 LOGISTICS

Logistic is divided into inbound and outbound perimeters.
The logistic inbound is defined by all logistics of parts that are required for the assembly of vehicules.
These informations are difficult to gather and to allocate to only one vehicle (model and dedicated assembly plant).
Currently, in the LCA studies, we consider a mean distance value of 2000 km (by trucks) for inbound logistic. (This value is approximately estimated by the logistic expert. A study of sensitivity show that inbound logistic is not the main contributor for the whole vehicle LCA result.

Abiotic depletion (fossil) potential	Reference (Twingo 2): inbound according to logistic expert = 2000km)	100%
	Inbound / 2	**-0,18%**
	Inbound x 2	**0,36%**

Acidification potential	Reference (Twingo 2): inbound according to logistic expert = 2000km)	100%
	Inbound / 2	**-0,43%**
	Inbound x 2	**0,85%**
Global Warming potential	Reference (Twingo 2): inbound according to logistic expert = 2000km)	100%
	Inbound / 2	**-0,16%**
	Inbound x 2	**0,32%**
Eutrophication potential	Reference (Twingo 2): inbound according to logistic expert = 2000km)	100%
	Inbound / 2	**-0,79%**
	Inbound x 2	**1,57%**
Photochemical ozone creation potential	Reference (Twingo 2): inbound according to logistic expert = 2000km)	100%
	Inbound / 2	**-0,17%**
	Inbound x 2	**0,35%**

Table 7 : Sensitivity study for inbound logistic

The logistic outbound is defined by the delivery of the vehicle in retail network. These informations (number of km, transportation mode) are already and easily available and are used in LCA.

In order to explain our choice of a distance of 2000kms concerning the inbound and considering multiple hypothesis made to obtain and treat data from parts transport from first rank suppliers to the factory (assembly), it is important to verify if hypothesis were reasonable and if data was not over or under-estimated. So, we chose to modify distance of this transport to observe if it consequently changes our results. We doubled supply chain distance, from 2000 to 4000 km.

Following table gives results concerning impacts potentials (only global ones). We observe changes on vehicle production phase because supply chain is only part of this step.

Impacts potentials	Relative gap (petrol vehicle)	Relative gap (diesel vehicle)
Abiotic depletion (kgSb-eq)	+ 0.29%	+ 0.33%
Acidification (kgSO_2-eq)	+ 1.20%	+ 0.94%
Eutrophication (kgPO_4-eq)	+ 2.18%	+ 1.31%
Global warming (kgCO_2-eq)	+ 0.27%	+ 0.32%
Photochemical ozone creation (kgC_2H_4-eq)	+ 0.34%	+ 0.44%

Table 8: Comparison of environmental impacts following a modification of supply transport, applied on an average Renault vehicle

We observe a logical increase of all impacts from this mileage increase. The consequences of larger distances are larger fuel consumption and then pollutant emissions. But those increases do not overpass 5%, our cutoff criteria.

We can highlight the low contribution of supply transport on environmental impacts over the global life cycle and the negligibility of an approximation on this parameter.

III.4.2 FACTORIES

III.4.2.1 Impacts

Every plant participating in Renault vehicle production is ISO14001 certified.

Since 1998, Renault checks and controls consumptions and emissions to improve environmental performance. Since 2012, these data are mandatory standards in France (Article 225 of Grenelle 2 French law). We use these data to conduct the LCA studies. The advantage is that all information is available and updated each year.The detail of data is described just bellow:

- Energy consumption (electricity, thermal),
- Water consumption (industrial, domestic),
- Atmospheric emissions (CO, CO_2, CH_4, N_2O, NO_x, SO_2, VOC),
- Waste quantities (standard, specials)

These values are available in the annual Energy and Environment reports, they are udated each year.

III.4.2.2 Allocations

Renault sites are dedicated to the manufacture of different engines, gearboxes or vehicles.
Impact allocation problems occur when a factory produces different engines and gearboxes, or when an assembly plant produces different cars.The contribution of each module needs to be estimated and calculated.

In our panel of plants, we could find assembly lines designed for vehicles, engines and gearboxes. In this case we have to identify the datas from vehicle and from mechanical.
Moreover, some factories produce different model on the same assembly line (vehicle or engines or gearboxes) and in this case the assumption is made that emissions are equally shared for vehicles that are assembled in the same factory. The same assumption is made concerning engine and gearbox.

All data necessary for the analysis and extracted from reports are gathered in tables' flows. These are available on the vehicle LCA study. These datas are extracted from the scorecard and table report issued from the plants management.

III.5 USE

III.5.1 USE: FUEL AND ELECTRICITY PRODUCTION

Fuel production step starts with oil extraction or electricity production and ends at sale to customer. This step is named “well to tank”.

Data necessary to calculate this step are:

- Mileage done by the vehicle during its total use phase defined by the functional unit.
- Energy type (Diesel, gasoline or electricity) and its quality (sulfur rate, electric production mix…)
- Vehicle’s consumption, available on the homologation certificate

The environmental flows associated to these consumptions (incoming or outgoing) are included in the software.
In addition, we take into account the country where the vehicle is used. Indeed, the electrical mix is significantly different depending on country of use.

III.5.2 USE: CAR USE PHASE

Impacts of this phase are calculated from a mileage defined in the functional unit and according to the NEDC (New Europeen Driving Cycle).
It requires the collection of the following data:

- CO, CO_2, HC, NOx, SO_2 and particles PM10 emissions
- Fuel and electricity consumption

Tailpipe emission data and fuel or electricity production are included in conformity certificates (excluding SO2 emissions).
Those certificates contain official vehicle type homologation data of Renault cars.

SO2 emissions depend on sulfur rate of Diesel fuel. They are calculated with the following formula:

$$\textbf{ppm of S} * 2*10^{-6} * \textbf{consumption (en g/km)} = \ldots\ \mathbf{gSO_2/km}$$

With density:
Gasoline = 747g/l
Diesel = 835g/l

In 2012, all newly launched vehicles in Europe comply with Euro V tailpipe emission regulation: sulfur rate in gasoline and diesel is 10 ppm.
From its engine technology, an electric vehicle does not produce any tailpipe emissions like CO_2, NO_X, SO_2 or particles.

III.5.3 USE : MAINTENANCE

Maintenance operations (except crash) are described in Table 9

Operation	Life cycle frequency according to Renault recommendations (Thermal vehicle)	Life cycle frequency according to Renault recommendations (Electric Vehicle)
Air-conditioning fluid change	1	1
Pb-battery change	1	1
Brake fluid change	1	1
Cooling fluid change	1	1
Windscreen washing liquid change	4	4
Drain	7	0
Tire change	3	3

Table 9: Operation and frequency of maintenance operations

Concerning the wash of vehicles, as all washes are the same from one product to another, the water consumption is not considered to calculate impacts and then, <u>not considered in Renault's studies</u>.

III.6 **<u>END OF LIFE</u>**

The end of life scenario is based on End of Life Vehicles Europeen directives (2000/53/CE and 2005/64/CE).

The recycling rate that has to be reached is 85% in term of recyclability and 95% in term of recoverability.

The recycling process follows the recomandation of the ISO 22628.

It takes into account the depollution phase, the dismantling of the parts and the shredding of the rest of the end of life vehicle.

Two different scenarios are modelled for the recycling phase:

- Scenario 1 – Reference scenario: we consider the processes for the dismantling and shredding of the end of life vehicle. Are also considered the recycling processes to produce secondary material, but recycling credits related to the production of the secondary material are not considered.

- Scenario 2: Recycling credits are estimated and included in the recycling phase results

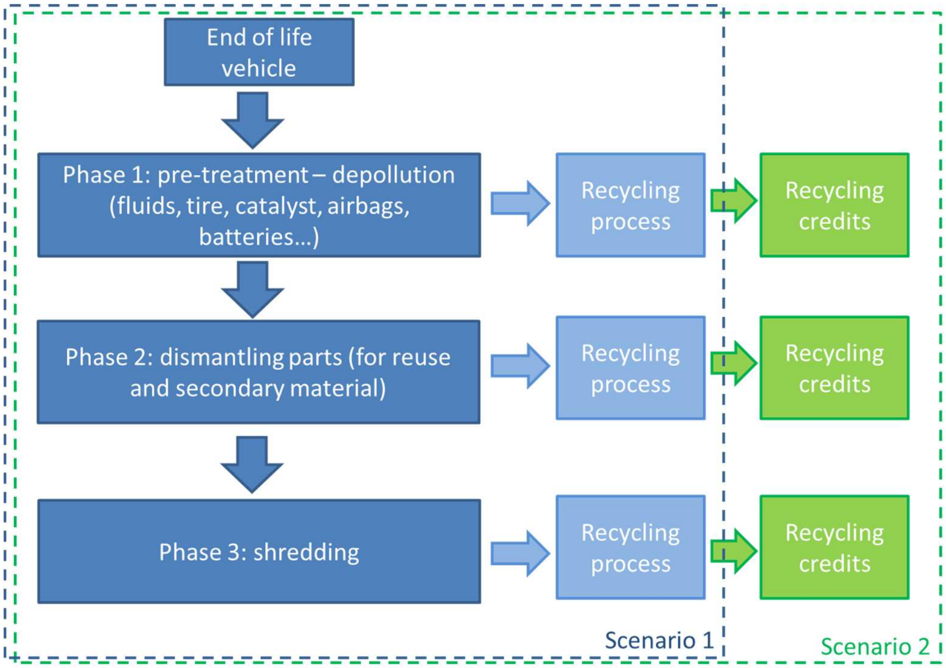


Figure 15 : Recycling modelling

Recycling Allocation:

Secondary material produced thanks to recycling processes can be considered as substitute for new material at production and consequently associated to a recycling credit.

Particular attention:

During the modelling phase of the production of the vehicle, data set used to model the production of raw material, provided by Thinkstep can take into account secondary material (For example, steel production takes into account the integration of secondary material).

This secondary material must not be considered during the end of life process to avoid double counting.

III.7 QUALITY OF DATA

Process	Data specification			Data source					
	Product specific	Specific to site	General	1	2	3	4	5	
Vehicle's production									
Vehicle composition (vehicle + engine + gearbox)	X			X					RENAULT – list of thanks to suppliers
Crude oil and ores extraction			X		X				THINKSTEP – Aver Thinkstep database of databases are sa List of used dataset
Steel production			X	X					THINKSTEP – Aver List of used dataset
Aluminum production			X	X					THINKSTEP – Aver List of used dataset
Polymers and plastics production			X			X			THINKSTEP – Aver List of used dataset
Other materials production (copper…)			X			X			THINKSTEP – Aver List of used dataset
Production activities (included assembly of engine, gearbox, vehicle)	X	X		X					RENAULT - Enviro
Vehicle treatment and paint	X	X		X					RENAULT - Enviro
Vehicle's transport to dealer	X	X		X					RENAULT – Logisti

Notes :
1) Measures
2) Calculations from mass balances and/or incoming data for the defined process
3) Extrapolation of data from a defined process or similar technology
4) Extrapolation of a defined process or similar technology
5) Estimations

Product specific data :	refers to processes specifically referring to vehicle
Site specific data :	concern data from sites invorlved in the vehicle production but not specific to the vehicle
General data :	what is left

Board source: Adapted from « Environmental Assessment of Products » - Volume 1 – H. Wenzel

Table 10: Origin and specifications of data collected during analysis

Process	Data specification			Data source type					
	Product specific	Specific to site	General	1	2	3	4	5	
Vehicle's use									
Life time	X				X				RENAULT – INRET
Fuel consumption	X			X					RENAULT – NEDC structure
Emissions	X			X	X				RENAULT – NEDC structure
Vehicle's end of life									
Elimination structures (Recovery, treatment)			X			X			THINKSTEP – Aver List of used dataset
Recovery rate	X				X				THINKSTEP – Aver List of used dataset
Vehicle's pre-treatment		X			X				THINKSTEP – Aver List of used dataset
Vehicle's dismantling		X			X				THINKSTEP – Aver List of used dataset
Energies									

Energy production (including electricity)			X			X			THINKSTEP – Avera List of used datasets

Notes :
Measures
2) Calculations from mass balances and/or incoming data for the defined process
3) Extrapolation of data from a defined process or similar technology
4) Extrapolation of a defined process or similar technology
5) Estimations

Product specific data : refers to processes specifically referring to vehicle
Site specific data : concern data from sites invorlved in the vehicle production but not specific to the vehicle
General data : what is left

Board source: Adapted from « Environmental Assessment of Products » - Volume 1 – H. Wenzel

Table 11: Origin and specifications of data collected during analysis (following and end)

III.8 OVERVIEW OF ASSUMPTIONS AND DEFINITIONS FOR A LCA

The table below presents a summary of all the assumptions and definitions considered in a LCA study.

Intended applications

- Complete our range of LCA studies in order to compare each new vehicle with its predecessor or with a similar existed vehicle in the range.
- Set up new unit process and LCI data sets (eg battery) to be used in a new calculation model
- Build a comprehensive science based dialogue with expert stakeholders inside and outside of the company

Scope of assessment

- Function of systems:

Transport of passengers in a vehicle

- Functional unit:

Transportation of persons in a vehicle, for a distance of 150 000 kms (~93 000 miles), during 10 years, respecting vehicle type approval regulations (e.g. NEDC driving cycle)

Comparability

- Comparable performance figures
- Cars with standard equipment and fittings

System boundaries

- The system boundaries include the entire life cycle of the cars (manufacturing, service life and recycling phase), according to cut-off criteria.

Cut-off criteria

- The assessment includes maintenance but not repairs
- No environmental impact credits are awarded for secondary raw materials produced
- Cut-off criteria applied in GaBi data records, as described in the software documentation (www.gabi-software.com)
- Explicit cut-off criteria, such as mass or relevant emissions, are defined at 99% for the vehicle's definition and 95% for incoming flows.

Allocation

- Allocations used in GaBi data, as described in the software documentation (www.gabi-software.com)
- Allocations for end of life is described in the end of life chapter of the report

Data basis

- Renault vehicle parts lists
- Material and mass information from the Renault IMDS
- Emission limits (for regulated emissions) laid down in current EU legislation
- The data used comes from the GaBi database or collected in Renault plants, suppliers or industrial partners

Life Cycle Inventory results

- Life Cycle Inventory results include emissions of CO2, CO, SO2, NOX, NMVOC, CH_4, as well as consumption of energy resources
- The impact assessment includes the environmental impact categories eutrophication potential, abiotic depletion potential, photochemical ozone creation potential, global warming potential for a reference period of 100 years and acidification potential
- Normalisation of the results to average impact per inhabitant values

Software

- Life Cycle Assessment software GaBi from Thinkstep, which release and update must be precised

Evaluation

- Evaluation of Life Cycle Inventory and impact assessment results, subdivided into life cycle phases and individual processes
- Comparisons of impact assessment results of the vehicles compared
- Interpretation of results

Table 12: Assumptions and definitions for the Life Cycle Assessment

IV LIFE CYCLE IMPACT ASSESSMENT

IV.1 INDICATORS CHOSEN FOR THE STUDIES

Environmental indicators were chosen in considering three criterias:
- Contributions known and supposed of automotive product.
- Diversity of ecosystems, local biodiversity, global resources depletion.
- Indicators positively considered by environmental experts and the European automotive industry.

The choice of indicators was validated by using the French matrix: adapted [ADEME 2011]

[ADEME 2011] Impact Assessment Proposals		EVALUATION			
		RELEVANCE	FEASABILITY	CONSISTENCY	FIABILITY
Global warming	✓	high	high	high	high
Abiotic depletion	✓	high	high	high	high
Water eutrophication	✓	medium	medium	medium	medium
Photochemical pollution	✓	medium	medium	medium	medium
Acidification	✓	medium	medium	medium	medium
Aquatic ecotoxicity	✗	medium	low	medium	low
Biodiversity	✗	low	low	medium	low
Land Use Change	✗	low	low	medium	low

Table 13: Impact assessment choice matrix

Concerning particles, even if they are a key topic for automotive industry, particularly for Diesel vehicles, they are not considered whithin an indicator. It is explained in the paragraph IV.12.

Characterization factors chosen are CML 2001 ones (More details at http://www.leidenuniv.nl/cml/ssp/databases/cmlia/cmlia.zip)

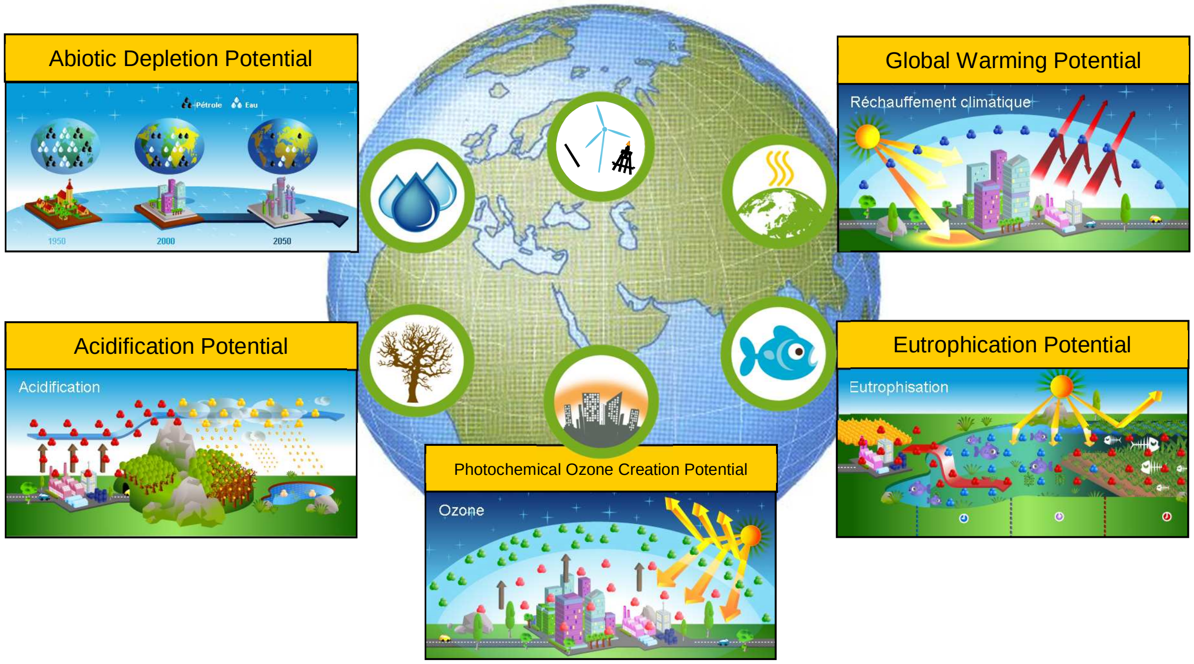


Figure 16: Impact categories chosen for the study

Indicators	Definition
Global Warming 100yr Potential (kg CO_2 equivalent)	Quantifies non-natural increase of greenhouse effect gas concentration (CO_2, N_2O, CH_4, refrigerants…) in the atmosphere and consequently of global warming potential.
Acidification Potential (kg SO_2 equivalent)	Characterize the acid substances increase (NOx, SO_2…) in lower atmosphere, source of acid rains and forests depletion.
Photochemical Ozone Creation Potential (kg Ethene equivalent)	Quantify the production of pollutant ozone (≠ to ozone layer), responsible of « ozone peaks », results of reaction of sunlight on NOx and volatile organic compounds. This ozone is irritating for respiratory system.
Eutrophication Potential (kg Phosphates equivalent)	Characterize introduction of nutrient (nitrogenous or phosphate compounds per example) providing proliferation of algae, which consequence is the asphyxia of the aquatic world
Abiotic Resource Depletion Potential (fossil) (MJ)	Quantify non-renewable energies (crude oil, coal…) consumption leading to resources and abiotic depletion.

Table 14: Environmental impacts categories selected and definition

The environmental impacts determined in the Life Cycle Assessments are representing a specific burden to the environment; therefore, they are measured in different units. For instance, the global warming potential is measured in CO2 equivalents and the acidification potential in SO2 equivalents. In order to make them comparable, a normalisation process is required. In our Life Cycle Assessments, the results are normalised with reference to the annual average environmental impact caused by Western Europe.

Indicators	Impact caused by Western Europe inhabitants x 10^{-6}
Abiotic Resource Depletion Potential (MJ)	30620200
Acidification Potential (kg SO_2 equivalent)	27354
Global Warming 100yr Potential (kg CO_2 equivalent)	4883200
Eutrophication Potential (kg Phosphates equivalent)	12822
Photochemical Ozone Creation Potential (kg Ethene equivalent)	8241

Table 15: EU 15 normalisation factors in accordance with CML 2001, Apr. 2013

IV.2 INDICATORS NOT CHOSEN

IV.2.1 HUMAN TOXICITY

It includes carcinogens and atmospheric pollution.

Concerning the automotive industry and particularly the use phase of the vehicle, toxicity potential impact is mainly coming from **particulate matters**.
These particles are fine dust from incomplete combustion. With a diameter inferior to 10µm, that can penetrate animal and human airway and cause asthma, inflammations or cancers.
PM 10 is only taken into account in human toxicity indicators.
In his research F. Querini [Querini, 2012] had studied the impact of different fuels on human toxicity (according to different methodologies). The results show that if Diesel fuel contribute to PM10 formation, the evolution of Euro standard have considerably reduce particles quantities and thus Diesel impact on toxicity.
On top of that, the LCA model takes into account only emission that follows Euro regulation and particulate matters are only measures since Euro 6 regulation. The consequence is that it is not possible to make a comparison between the wem vehicle and the replaced one.
When comparison will be possible particles and human toxicity indicator will be disclosed.

Focus on Carcinogens substances
Benzene is a substance contained in a low quantity (< 1%) in HC (unburned hydrocarbons emitted in exhaust gas), which carcinogen factor is recognised. However, there is not any limitation value, so it is difficult to evaluate its impact on human heath. In a prevention purpose, its concentration should be as low as possible.

IV.2.2 WATER CONSUMPTION

Water consumption integration in a LCA is a complex problem which methodology has been recently developed. (*ISO14046*). We need to identify:

- Water used, treated and returned to natural environment (like washing water), from water consumed (demineralized water for paints)
- Process water used in multiple cycles, paying attention in considering it once.
- Water origin: groundwater cannot return there
- Geographic context: Water consumption importance is not the same in Europe or in Africa (*water scarcity* indicator needed)

Conscious of problems linked to water consumption and in an ISO 14001 approach, Renault works for reducing its use. In this way:

- Group's water consumption decreased of up to 55% from 1998 to 2010, associated to a 22,7% increase of the production
- Water consumption per vehicle produced decreased, from 11,3 m^3/veh, to a small 4,14 m^3/veh, representing a 63.3% decrease from 1998 to 2010.

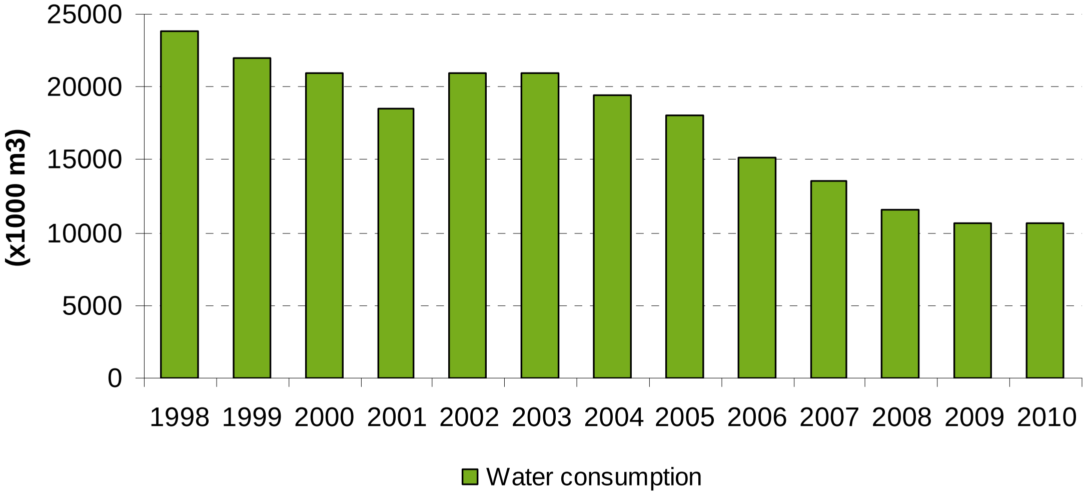


Figure 17: Water consumption reduction in Renault factories

From the ISO 14001 deployment in the group, Renault obtained a large amount of data about the different water sourcings. Water footprint integration will be the next step of the LCA deployment at Renault, as well as human toxicity. For the time being, Renault focuses on reducing the group's global water consumption.

IV.2.3 ROAD SAFETY

Although Renault dedicates a lot in this problematic, it is here out of the LCA context as it is a non-environmental issue.

IV.2.4 WASTE QUANTITY FROM THE SUPPLY CHAIN

Renault can control waste production provided on major steps of the vehicle production (assembly line, engine and gearbox production, Figure 18), but no all along supply chain (implication in an ISO 14001 approach or use of an eco indicator tool). For these processes and raw materials extraction, waste quantities come from software databases.

Figure 18: Evolution of packaging waste quantities at production. Quantity in kg per vehicle from 1996 to 2010

IV.2.5 NON-EXHAUST EMISSIONS

Non-exhaust emissions and especially particulate matter non-exhaust emissions are of course part of the emissions while driving. National emission inventories include copper in their scope and the transport sector is responsible for 87% of the total emissions. Road traffic accounts for a little bit more than a half of this amount (CITEPA SECTEN report April 2011). Some publications also address vegetation contaminations near road network.

Nevertheless, there are very few data, to be used as a recognized emission factor database, to achieve reliable calculations for those emissions. As there exists no regulation addressing this scope, industry performs tests to evaluate functional properties but those measurements do not allow evaluating lifetime wear emissions.

Another difficulty is linked to the various origins of those wear particulates:
- Brakes seam to be the main source of emissions. But the composition of the particulate matter is very much dependent on the technology; disc brakes are much more emissive than drum brakes.
- Due to the geometry of clutches, the particulate emissions are virtually zero.
- The tire debris.

In addition, the composition of those wear particulates depends very much on the supplier and some of those parts do not stand for the lifetime of the car and can be changed without any control of the supply chain by the manufacturer.
Taking only account about the copper emission factor coming from COPERT methodology would probably be as restrictive as not considering this source of emissions at all.

Any way, ignoring non-exhaust particulate matter probably leads to underestimate the absolute result of the life cycle impact analyses, but this is not a problem for a wide comparative approach, tires and break wear being included in all cars whatever there are EV or fossil fuelled.

V STANDARD HYPOTHESIS SENSITIVITIES

In order to ensure coherence of hypotheses performed and to measure the influence of some parameters, we performed a sensitivity analysis. We apply an important change to a parameter to check if the result is significant or negligible.

V.1 CONSIDERING FACTORIES?

V.1.1 FACTORIES MASS

We can consider that a factory (for example Tanger) is mainly made of concrete and steel. The main assumptions are:
- 40 kg of steel per meter square built;
- 500 kg of concrete per meter square built

With this assumption and since we have on the one hand the information of vehicles and engines produced for each plant, and on the other hand the estimated surface area for each plant, we can estimate the factory mass per unit produced (per vehicle or per engine).

The results are the following one:
47 kg of the factory for diesel vehicle
49 kg of the factory for gasoline vehicle

These values are quite negligible. Moreover, concrete represents 90% of the factory's mass and it is mainly constituted of aggregate (sand, pebbles). Quantity of energy necessary for its construction is low comparing to energy consumed by the system, and then negligible.
Considering now impacts, we show that the part of the factory allocated to each car is negligible on the global life cycle.

V.1.2 IMPACT CALCULATION

Data from concrete production environmental impacts comes from report http://www.nrmca.org/sustainability/EPDProgram/Downloads/NRMCA%20EPD%2010.08.2014.pdf giving the impact of 1m3 of concrete composed of 80% of aggregate and needing 2187 MJ (0,94MJ per kg).
Production process of steel is based on GaBi database corresponding to European production, without considering an eventual recycling.
For logistics considerations, all of products are produced in Europe.
Quantities of energy consumed by machines to build the building are not included (cranes, diggers…). However, considering results bellow, in doubling environmental impacts values of the 50kg of the factory per vehicle, we are still under 1% for each impact on the global life cycle.

Then we can consider factories construction (and other infrastructures) as negligible on the global life cycle.

1,6l 16v (petrol)	Factory impact	System's impact on its life cycle (without considering factories mass)	Proportion on life cycle
Impacts potentials			
Abiotic depletion (kgSb-eq)	0.076	219.79	0.034%
Acidification (kgSO_2-eq)	0.12	60.10	0.20%
Eutrophication (kgPO_4-eq)	0.005	5.35	0.093%
Global warming (kgCO_2-eq)	16.4	34762	0.047%
Photochemical ozone creation (kgC_2H_4-eq)	0.01	12.44	0.080%

Table 16: Part of factory's construction a petrol vehicle's life cycle

1,5l dCi (diesel)	Factory impact	System's impact on its life cycle (without considering factories mass)	Proportion on life cycle
Impacts potentials			
Abiotic depletion (kgSb-eq)	0.073	169.55	0.043%
Acidification (kgSO_2-eq)	0.12	56.84	0.21%
Eutrophication (kgPO_4-eq)	0.004	6.92	0.057%
Global warming (kgCO_2-eq)	15.6	25463	0.061%
Photochemical ozone creation (kgC_2H_4-eq)	0.01	9.25	0.011%

Table 17: Part of factory's construction a diesel vehicle's life cycle

V.2 FACTORIES ALLOCATIONS

In order to justify established hypothesis or the need of amelioration of factories consumptions and emissions allocations (by the eco-risk tool), we increase values of those parameters by over 10% for all factories. Variations for diesel and petrol vehicles are gathered in the following table:

Impacts potentials	Relative gap (petrol vehicle)	Relative gap (diesel vehicle)
Abiotic depletion (kgSb-eq)	+ 0.04%	+ 0.20%
Acidification (kgSO_2-eq)	+ 0.18%	+ 0.39%
Eutrophication (kgPO_4-eq)	+ 0.19%	+ 0.28%
Global warming (kgCO_2-eq)	+ 0.15%	+ 0.33%
Photochemical ozone creation (kgC_2H_4-eq)	+ 0.44%	+ 0.61%

Table 18: Comparison of environmental impacts following a 10% increase of Renault factories' consumptions and emissions, applied on an average Renault vehicle

We note that none of impacts values reaches 0.7 on the global life cycle. It reveals the weak incidence of an allocation error of factories flows, which contribution stays under 1%.

REMARK: If part of the factories remains weak comparing to the global life cycle of a vehicle, any reduction of consumptions or emissions is beneficial.

V.3 HC ADDITIONAL SOURCE

V.3.1 PROBLEMATIC

The issue deals here with the potential evaporation of hydrocarbon vapors (petrol) during tank filling:
- From petrol delivery truck to petrol station
- From petrol station fuel pump to vehicle tank.

Because of petrol's volatility (not concerning diesel), part of hydrocarbons is emitted in the atmosphere bringing a potential increase of photochemical ozone creation. Moreover, presence of benzene (0.7% in petrol vapors) brings a public heath problem because it is a carcinogen agent.

Current European legislation does not impose vapor recovery systems on those two steps (unless recovery systems are being developed). Automotive manufacturers ensure non-evaporation of petrol vapors once filler hose closed (canister system, tank's sealing)

Here is a sensitivity analysis when the gas station is equipped with a recovery system for vats filling. We only consider the impact on which the constructor can act.

REMARK: During petrol station vats filling, the emitted quantity allocated to each vehicle is the same than the one emitted during tank filling (same quantity of petrol consumed and same hypothesis concerning evaporation calculation. So we double variation of impact measured.

V.3.2 HYPOTHESES AND CALCULATIONS

For environmental impacts calculation, we consider hydrocarbon vapors to HC even if those are quite different (cf remark):

This pattern considers two hypotheses:
Liquid/vapor balance of petrol responds to Clausius-Clapeyron equation or pure, which form is: $\log P = A/T + B$
Petrol vapor responds to ideal gas law.

1) We consider averaged over the year the vapor tension of petrol to a median summer/winter value: 60kPa at 37.8℃ (100° Fahrenheit)

Vapor tension is equally placed between Pentane and Hexane vapor tensions, which equations are:

$$\log P_{pentane} = -1458/T + 6.27$$

$$\log P_{hexane} = -1649/T + 6.83$$

with decimal log, P in kPa, T Kelvin, data from Handbook of Chemistry and Physics.

We consider petrol as a pure:
Average molar weight between pentane (72) and hexane (86): 79
Average coefficient between pentane and hexane: $\log P_{petrol} = -1550/T + B$; we calculate B with reference vapor tension : $\log P_{petrol} = -1550/T + 6.76$ (1)

With equation (1), we calculate vapor tension a different temperatures. At 20℃, $P_{petrol} = 30$ kPa.

2) We consider 1 liter of atmosphere saturated of petrol vapor at atmospheric pressure (101.3 kPa) and at 20℃ (average temperature supposed).

Petrol partial pressure = 30 kPa

Total pressure = 101.3 kPa

In ideal gas approximation, total number of moles of gas = 1/22.4

Number of moles of petrol = (1/22.4) x (30/101.3)

Weight of petrol's weight
= (1/22.4) x (30/101.3) x 79 = 1.0 g of petrol vapor per liter of atmosphere in the tank.

Quantity of HC emitted during tank filling approaches 0.079 g/km for a vehicle consuming 7.9 liters/100 km.

At 20℃, this emission is very close to Euro IV emission regulation. If average tank temperature is 10℃, P_{petrol} becomes 19 kPa and emission approaches 0.052 g/km

V.3.3 RESULTS

Figure 44 represents evolution of photochemical ozone creation's impact during use phase, with a tank a 10℃ and 20℃ considering previous hypothesis.

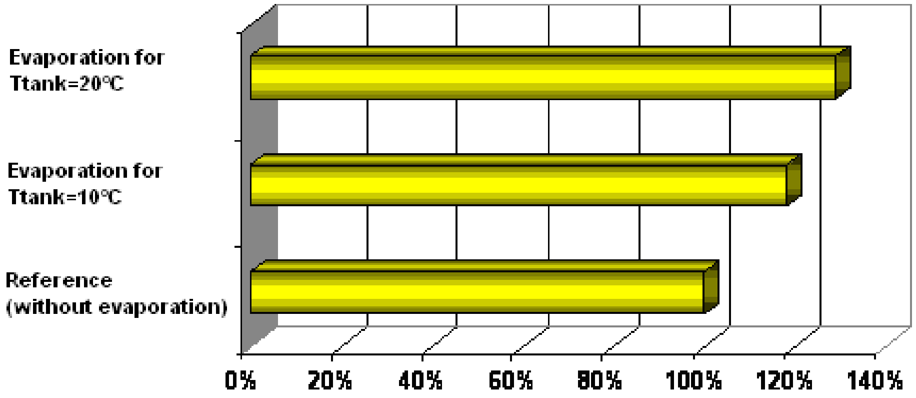


Figure 19: Evolution of photochemical ozone creation potential, function of tank temperature (i.e. petrol vapors)

Impact potential	Reference (without evaporation)	At 10℃ (HC = + 0,052 g/km)	At 20℃ (HC = + 0,079 g/km)	Relative gap [10℃ – 20℃]
Photochemical ozone (kgC_2H_4-eq.)	14.9	17.8	19.3	+ [19 - 29] %

Table 19: Value of photochemical ozone creation potential for use phase, function of tank temperature (i.e. petrol vapors)

Fuel vapors are very far from being negligible. There is a real need of vapors recovery.

However, this emission does not have the same geographic dispersion as exhaust gas.

Moreover, as stated previously, in many countries (England, United States…), recovery systems are compulsory and would be extended to rest of the Europe.

Currently in France, May 17th of 2001 order (http://aida.ineris.fr/textes/arretes/text3272.htm) relative to reduction of volatile organic compounds emissions due to petrol tank filling mandates recovery systems in gas station providing more than 3000 m3 per year. Moreover, any newly built gas station must be equipped with that system if it provides more than 500 m3 per year. A bill is currently studied to mandate those systems compulsory for any gas station.
(http://www.assemblee-nationale.fr/12/propositions/pion3471.asp).

Then Renault does not consider these pollutant emissions in the vehicle life cycle.

However, this sensitivity analysis reveals the need of regulating it quickly on European perimeter.

VI METHODOLOGY REPORT APPENDIX

VI.1 **REFERENCES**

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VI.2 **ABBREVIATION LIST**

ADP: Abiotic depletion potential

AP: Acidification potential

CML 2001: name of the environmental impacts calculation method from the Institute of Environmental Sciences of Lieden Faculty of Science

ECU: Electronic control unit

ELV: End of life vehicle

EP: Eutrophication potential

EV: Electric vehicle

GWP: Global warning potential

ICE: Internal Combustion Engine

ISO: International Organization for Standardization

LCA: Life Cycle Assessment

LCI: Life Cycle Inventory

NEDC: New Europeen Driving Cycle

POCP: Photochemical Ozone Creation Potential

Z.E.: “Zero Emission”: commercial denomination of Renault electric vehicles.

VI.3 **EUROPEAN EMISSIONS REGULATIONS**

In mg/km

Diesel

REGULATION	EURO4	EURO5	EURO6
Nitrous Oxides (NOx)	250	180	80
Carbon monoxide (CO)	500	500	500
Hydrocarbons (HC)	-	-	
HC+NOx	300	230	170
Particulates (PM)	25	5	5

Table 20: European emission standards for diesel engines

Petrol, LPG and NG

REGULATION	EURO4	EURO5	EURO6
Nitrous Oxides (NOx)	80	60	60
Carbon monoxide (CO)	1000	1000	1000
Hydrocarbons (HC)	100	100	100
Particulates (PM)	25	5	5
Non-methanous hydrocarbons	-	68	68

Table 21: European emission standards for petrol, LPG and NG engines

REMARK: For EV, as it is a zero emission from engine's operation, it fits all EURO regulations.

VI.4 LIST OF DATASETS FROM THINKSTEP USED IN RENAULT MODEL FOR TWINGO STUDY

For the TWINGO study, Renault vehicle model has runned with database 6.11 service pack 27. Some datasets are not up to date since they were used previously and have moved from Thinkstep availabled databases to paid extensions that Renault did not subscripted.

Process	Source process	date de mise à jour
DE: Lead (99,995%)	PE	2014
EU-27: Sulphuric acid (96%)	PE	2014
EU-27: Water (desalinated,deionised)	PE	2014
DE: Ceramic		2006
GLO: Palladium mix	PE	2014
GLO: Platinum mix	PE	2014
GLO: Rhodium mix	PE	2014
EU-27: Copper Wire Mix	DKI/ECI	2014
DE: Copper mix (99,999% from electrolysis)	PE	2014
RER: PWB FR4 (2l; 2s; AuNi finishing)	PE	2006
RER: IC unspecific (average)	PE	2006
DE: Capacitor SMD ceramic (average)	PE	2006
DE: Capacitor SMD tantal (average)	PE	2006
DE: Resistor SMD (average)	PE	2006
DE: Diode SMD small (average)	PE	2006
DE: Oscillator SMD (average)	PE	2006
Components mixer	PE	2006
RER: Assembly line SMD (simple) throughput 1000/day	PE	2006
Electronic (ABS/ESP)		2004
DE: Transistor small (average) PE	PE	2006
DE: Coil SMD miniature coil (average) PE	PE	2006
Card (Electronic part)	PE	2006
Electronic (Sensor chases clutch release)		2004
EU-27: Aluminium clean scrap remelting & casting (2010) EAA <p-agg>	PE	2006
RER: Printed wired board FR4 (4l; 2s; AuNi finishing) PE	PE	2006
DE: Capacitor AL-ELKO General purpose (Average) PE	PE	2006
DE: Transistor SMD power large (average) PE	PE	2006
DE: Diode SMD large (average) PE	PE	2006
Airbag (Electronic part)		2004
DE: LED (average) PE	PE	2006
Card reader (electronic part)		2004
DE: Filter SMD (average) PE	PE	2006
Electronic (Sensor height)		2004
RER: IC unspecific (average) PE	PE	2006
Electronic (Anti-theft)		2004
Plastic for electronique	PE	2006
Electronic (Control panel)	PE	2004
Electronic (Sensor pedals accelerator)		2004

Automatic parking brake (Electronic part)		2004
DE: Coil SMD chip coil (average) PE	PE	2006
Relay (Electric power assisted steering) PE	PE	2006
Electric power assisted steering (Electronic part)		2004
Electronic (Under hood module)		2004
Electronic (Body Control Unit)		2004
Engine Control (Electronic part)		2004
EU-27: Lubricants at refinery	PE	2014
DE: Cooling liquid		2006
DE: Glass wash fluid		2006
DE: Brake fluid		2006
EU-27: Diesel mix at refinery	PE	2014
EU-27: Gasoline mix (regular) at refinery	PE	2014
EU-27: Gasoline mix (prenium) at refinery	PE	2014
EU-27: Float glass	PE	2014
DE: Ceramic		2006
DE: Steel cast part allowed (automotive)	PE	2014
EU-27: Electricity grid mix	PE	2014
EU-27: Thermal energy from natural gas	PE	2014
DE: Steel billet (20MoCr4)	PE	2014
DE: Steel billet (16MnCr5)	PE	2014
DE: Steel billet (100Cr6)	PE	2014
DE: Steel billet (28Mn6)	PE	2014
DE: BF Steel billet/slab/bloom	PE	2014
EU-27: Aluminium sheet mix	PE	2014
EU-27: Electricity grid mix	PE	2014
DE: Aluminium sheet deep drawing	PE	2014
EU-27: Aluminium ingot mix	PE	2014
EU-27: Electricity grid mix	PE	2014
EU-27: Thermal energy from natural gas	PE	2014
DE: Aluminium die-cast part	PE	2014
EU-27: Electricity grid mix	PE	2014
EU-27: Thermal energy from natural gas	PE	2014
DE: Cast iron part (automotive)	PE	2014
EU-27: Electricity grid mix	PE	2014
EU-27: Compressed air	PE	2014
EU-27: Lubricants at refinery	PE	2014
DE: Steel sheet HDG	PE	2014
GLO: Steel sheet stamping and bending (5% loss)	PE	2014
GLO: Steel turning	PE	2014
EU-27: Electricity grid mix	PE	2014
DE: Steel billet (20MoCr4)	PE	2014
DE: Steel billet (16MnCr5)	PE	2014
DE: Steel billet (100Cr6)	PE	2014
DE: Steel billet (28Mn6)	PE	2014
DE: BF Steel billet/slab/bloom	PE	2014

GLO: Silver mix	PE	2014
DE: Zinc redistilled mix	PE	2014
GLO: Gold mix (primary and copper route)	PE	2014
EU-27: Brass (CuZn20)	PE	2014
DE: Ferro chrome mix	PE	2014
GLO: Silicon mix (99%)	PE	2014
CN: Magnesium	PE	2014
ZA: Feroo manganese	PE	2014
GLO: Feroo silicon mix	PE	2014
DE: Nd-Fe-Dt Magnet with metal alloy input	PE	2014
GLO: Ferro nickel (29%)	PE	2014
RER: Stainless steel cold rolled coil (304)	Eurofer	2014
RER: Stainless steel cold rolled coil (316)	Eurofer	2014
EU-27: Aluminium ingot mix	PE	2014
DE: BF Steel billet/slab/bloom	PE	2014
DE: Copper mix (99,999% from electrolysis)	PE	2014
CN: Magnesium	PE	2014
DE: EAF Steel billet/Slab/Bloom	PE	2014
DE: Tin plate	BUWAL	2006
DE: Zinc redistilled mix	PE	2014
GLO: Ferro nickel (29%)	PE	2014
EU-27: Aluminium ingot mix	PE	2014
EU-27: Electricity grid mix	PE	2014
EU-27: Thermal energy from natural gas	PE	2014
DE: Aluminium die-cast part	PE	2014
DE: Underbody protection (PVC)	PE	2011
DE: Seam sealing (PVC)	PE	2011
DE: Cavity preservation	PE	2011
DE: Primer water-based	PE	2011
DE: Coating electrodeposition mix	PE	2011
DE: Base coat water-based (red; metallic)	PE	2011
DE: Clear coat solvent-based (2K)	PE	2011
RER: Nylon 6,6 granulate (PA6,6)	ELCD/Plastics Europe	2014
RER: Nylon 6 granulate (PA6)	ELCD/Plastics Europe	2014
RER: Nylon 6,6 GF30 compound (PA6,6 GF30)	ELCD/Plastics Europe	2014
DE: Polyamide 6,12 granulate (PA6,12)	ELCD/Plastics Europe	2014
RER: Polyethylene low density granulate (PELD)	ELCD/Plastics Europe	2014
RER: Polyethylene high density granulate (PEHD)	ELCD/Plastics Europe	2014
RER: polypropylene granulate (PP)	ELCD/Plastics Europe	2014
DE: polypropylene/Ethylene Propylene Diene Elastomer Granulate (PP/EPDM TPE-O) mix	PE	2014

DE: Nitrile rubber (NBR)	PE	2006
DE: Nitrile butadiene rubber, incl. MMA (NBR-speciality)	PE	2014
DE: Ethylene Propylene Diene Elastomer (EPDM)	PE	2014
DE: Styrene-Butadiene Rubber (SBR) Mix	PE	2014
DE: Sheet Moulding Compound resin mat (SMC)	PE	2014
RER: Polyurethane flexible foam (PU)	Plastics Europe	2014
RER: Polyurethane rigide foam (PU)	Plastics Europe	2014
EU-27: Talcum powder (filler)	PE	2014
DE: Glass fibres	PE	2014
RER: Polymethylmethacrylate-ball (PMMA)	ELCD/Plastics Europe	2014
RER: Polyvinylchloride granulate (suspension, S-PVC)	ELCD/Plastics Europe	2014
FR: Polyoxymethylene granulate (POM)	PE	2014
RER: Acrylonitrile-butadiene-styrene granulate (ABS)	ELCD/Plastics Europe	2014
DE: Polystyrene (PS) mix	PE	2014
RER: Polybutadiene granulate (PB)	ELCD/Plastics Europe	2014
EU-25: Polycarbonate granulate (PC)	Plastics Europe	2014
RER: Polyethylene terephtalate granulate (PBT, amorphe)	ELCD/Plastics Europe	2014
RER: Epoxy resin	Plastics Europe	2014
DE: Polyester Resin unsatured (UP)	PE	2014
DE: Polybutylene Terephthalate Granulate (PBT) mix	PE	2014
RER: Styreneacrylonitrile (SAN)	Plastics Europe	2014
EU-27: Electricity grid mix	PE	2014
DE: Plastic injection moulding part (unspecific)	PE	2014
EU-27: Tap water (groundwater)	PE	2014
RER: Nylon 6,6 granulate (PA6,6)	ELCD/Plastics Europe	2014
RER: Nylon 6 granulate (PA6)	ELCD/Plastics Europe	2014
RER: Nylon 6,6 GF30 compound (PA6,6 GF30)	ELCD/Plastics Europe	2014
DE: Polyamide 6,12 granulate (PA6,12)	ELCD/Plastics Europe	2014
RER: Polyethylene low density granulate (PELD)	ELCD/Plastics Europe	2014
RER: Polyethylene high density granulate (PEHD)	ELCD/Plastics Europe	2014
RER: polypropylene granulate (PP)	ELCD/Plastics Europe	2014
DE: polypropylene/Ethylene Propylene Diene Elastomer Granulate (PP/EPDM TPE-O) mix	PE	2014
DE: Nitrile butadiene rubber, incl. MMA (NBR-speciality)	PE	2014
DE: Ethylene Propylene Diene Elastomer (EPDM)	PE	2014
DE: Styrene-Butadiene Rubber (SBR) Mix	PE	2014
DE: Sheet Moulding Compound resin mat (SMC)	PE	2014

RER: Polyurethane flexible foam (PU)	Plastics Europe	2014
RER: Polyurethane rigide foam (PU)	Plastics Europe	2014
EU-27: Talcum powder (filler)	PE	2014
DE: Glass fibres	PE	2014
RER: Polymethylmethacrylate-ball (PMMA)	ELCD/Plastics Europe	2014
RER: Polyvinylchloride granulate (suspension, S-PVC)	ELCD/Plastics Europe	2014
FR: Polyoxymethylene granulate (POM)	PE	2014
RER: Acrylonitrile-butadiene-styrene granulate (ABS)	ELCD/Plastics Europe	2014
DE: Polystyrene (PS) mix	PE	2014
RER: Polybutadiene granulate (PB)	ELCD/Plastics Europe	2014
EU-25: Polycarbonate granulate (PC)	Plastics Europe	2014
RER: Polyethylene terephtalate granulate (PBT, amorphe)	ELCD/Plastics Europe	2014
RER: Epoxy resin	Plastics Europe	2014
DE: Polyester Resin unsatured (UP)	PE	2014
DE: Polybutylene Terephthalate Granulate (PBT) mix	PE	2014
RER: Styreneacrylonitrile (SAN)	Plastics Europe	2014
EU-27: Electricity grid mix	PE	2014
DE: Plastic injection moulding part (unspecific)	PE	2014
EU-27: Tap water (groundwater)	PE	2014
RER: Nylon 6,6 granulate (PA6,6)	ELCD/Plastics Europe	2014
RER: Nylon 6 granulate (PA6)	ELCD/Plastics Europe	2014
RER: Nylon 6,6 GF30 compound (PA6,6 GF30)	ELCD/Plastics Europe	2014
DE: Polyamide 6,12 granulate (PA6,12)	ELCD/Plastics Europe	2014
RER: Polyethylene low density granulate (PELD)	ELCD/Plastics Europe	2014
RER: Polyethylene high density granulate (PEHD)	ELCD/Plastics Europe	2014
RER: polypropylene granulate (PP)	ELCD/Plastics Europe	2014
DE: polypropylene/Ethylene Propylene Diene Elastomer Granulate (PP/EPDM TPE-O) mix	PE	2014
DE: Nitrile butadiene rubber, incl. MMA (NBR-speciality)	PE	2014
DE: Ethylene Propylene Diene Elastomer (EPDM)	PE	2014
DE: Styrene-Butadiene Rubber (SBR) Mix	PE	2014
DE: Sheet Moulding Compound resin mat (SMC)	PE	2014
RER: Polyurethane flexible foam (PU)	Plastics Europe	2014
RER: Polyurethane rigide foam (PU)	Plastics Europe	2014
EU-27: Talcum powder (filler)	PE	2014
DE: Glass fibres	PE	2014

RER: Polymethylmethacrylate-ball (PMMA)	ELCD/Plastics Europe	2014
RER: Polyvinylchloride granulate (suspension, S-PVC)	ELCD/Plastics Europe	2014
FR: Polyoxymethylene granulate (POM)	PE	2014
RER: Acrylonitrile-butadiene-styrene granulate (ABS)	ELCD/Plastics Europe	2014
DE: Polystyrene (PS) mix	PE	2014
RER: Polybutadiene granulate (PB)	ELCD/Plastics Europe	2014
EU-25: Polycarbonate granulate (PC)	Plastics Europe	2014
RER: Polyethylene terephtalate granulate (PBT, amorphe)	ELCD/Plastics Europe	2014
RER: Epoxy resin	Plastics Europe	2014
DE: Polyester Resin unsatured (UP)	PE	2014
DE: Polybutylene Terephthalate Granulate (PBT) mix	PE	2014
RER: Styreneacrylonitrile (SAN)	Plastics Europe	2014
DE: Latex concentrate (mix-renault)	PE	2014
RER polyvinylchloride resin (B-PVC)	ELCD/Plastics Europe	2014
DE: Latex concentrate (mix-renault)	PE	2014
DE: Styrene-Butadiene Rubber (SBR) Mix	PE	2014
RER: Polyurethane flexible foam (PU)	Plastics Europe	2014
RER: Epoxy resin	Plastics Europe	2014
DE: Polyester Resin unsatured (UP)	PE	2014
DE: Tire 175/70R13 Silica/Rayon [PP]		2000
EU-27: Electricity grid mix	PE	2014
DE: Electricity grid mix	PE	2014
US: Electricity grid mix	PE	2014
GB: Electricity grid mix	PE	2014
ES: Electricity grid mix	PE	2014
FR: Electricity grid mix	PE	2014
BE: Electricity grid mix	PE	2014
ENTSO: Electricity grid mix	PE	2014
JP: Electricity grid mix	PE	2014
CN: Electricity grid mix	PE	2014
RU: Electricity grid mix	PE	2014
EU-27: Gasoline mix (prenium) at filling station	PE	2014
EU-27: Diesel mix at filling station	PE	2014
EU-27: Liquefied Petroleum Gas (LPG) (70% propane, 30% butane)	PE	2014
EU-27: Tap water (groundwater)	PE	2014
EU-27: Thermal energy from heavy fuel oil (HFO)	PE	2014
EU-27: Thermal energy from natural gas	PE	2014
EU-27: Thermal energy from LPG	PE	2014
ENTSO: Electricity grid mix	PE	2014
EU-27: Process steam from natural gas 85%	PE	2014
EU-27: Commercial waste in municipal waste incinerator	PE	2014

EU-27: Landfill (Commercial waste for municipal disposal; FR, UK, FI, NO)	PE	2014
RER: Articuled lorry (40t) incl. Fuel	ELCD	2014
EU-27: Rail transport incl. Fuel	PE	2014
EU-27: Barge incl. Fuel	PE	2014
EU-27: Container ship ocean incl. Fuel	PE	2014
EU-27: Gasoline mix (regular) at filling station	PE	2014
EU-27: Diesel mix at filling station	PE	2014
EU-27: Liquefied Petroleum Gas (LPG) (70% propane, 30% butane)	PE	2014
EU-27: Electricity grid mix	PE	2014
DE: Electricity grid mix	PE	2014
US: Electricity grid mix	PE	2014
GB: Electricity grid mix	PE	2014
ES: Electricity grid mix	PE	2014
FR: Electricity grid mix	PE	2014
BE: Electricity grid mix	PE	2014
ENTSO: Electricity grid mix	PE	2014
JP: Electricity grid mix	PE	2014
CN: Electricity grid mix	PE	2014
RU: Electricity grid mix	PE	2014
EU-27: Lubricants at refinery	PE	2014
DE: Cooling liquid		2006
DE: Glass wash fluid		2006
DE: Brake fluid		2006
DE: Lead (99,995%)	PE	2014
EU-27: Sulphuric acid (96%)	PE	2014
EU-27: Water (desalinated,deionised)	PE	2014
DE: Tire 175/70R13 Silica/Rayon [PP]		2000
DE: Platinum recycling		2004
DE: Palladium recycling		2004
DE: Rhodium recycling		2004
GLO: Palladium mix (aps)	PE	2014
GLO: Platinum mix (aps)	PE	2014
GLO: Rhodium mix (aps)	PE	2014
RER: Plastic granulate secondary (unspecific)		2001
RER: polypropylene granulate (PP) (aps)	ELCD/Plastics Europe	2014
DE: polypropylene/Ethylene Propylene Diene Elastomer Granulate (PP/EPDM TPE-O) mix (aps)	PE	2014
RER: Acrylonitrile-butadiene-styrene granulate (ABS) (aps)	ELCD/Plastics Europe	2014
DE: polyethylene High Density Granulate (HDPE/PE-HD) Mix (aps)	PE	2014
DE: Copper Recycling Hüttenwerke Kayser AG		2002
DE: Copper mix (99,999% from electrolysis) (aps)	PE	2014
RER: Aluminum ingot secondary	BUWAL	2006
EU-27: Aluminium ingot mix (aps)	PE	2014

DE: Steel cold rolled (electric arc furnace)		2006
DE: BF Steel billet/slab/bloom (aps)	PE	2014
EU-27: Waste incineration of plastics (unspecified) fraction in municipal solid waste (MSW)	ELCD/CEV	2014
EU-27: Landfill (Commercial waste for municipal disposal; FR, UK, FI, NO)	PE	2014
DE: Scrap tire recovery (cement works)		2000
EU-27: Thermal energy from hard coal renault (aps)		2014
DE: Used oil refinery		1997
RER: Incineration of used oil		2006
EU-27: Heavy fuel oil at refinery (1.0wt.% S, Copy) (aps)		2014
EU-27: Lubricants at refinery (aps)	PE	2014
EU-27: Thermal energy from light fuel oil (LFO) (aps)	PE	2014
EU-27: Diesel mix at refinery (aps)	PE	2014
EU-27: Gasoline mix (regular) at refinery (aps)	PE	2014
RER: Lead (secondary)		2001
DE: Lead (99,995%) (aps)	PE	2014
EU-27: Landfill of glass/inert waste	PE	2014