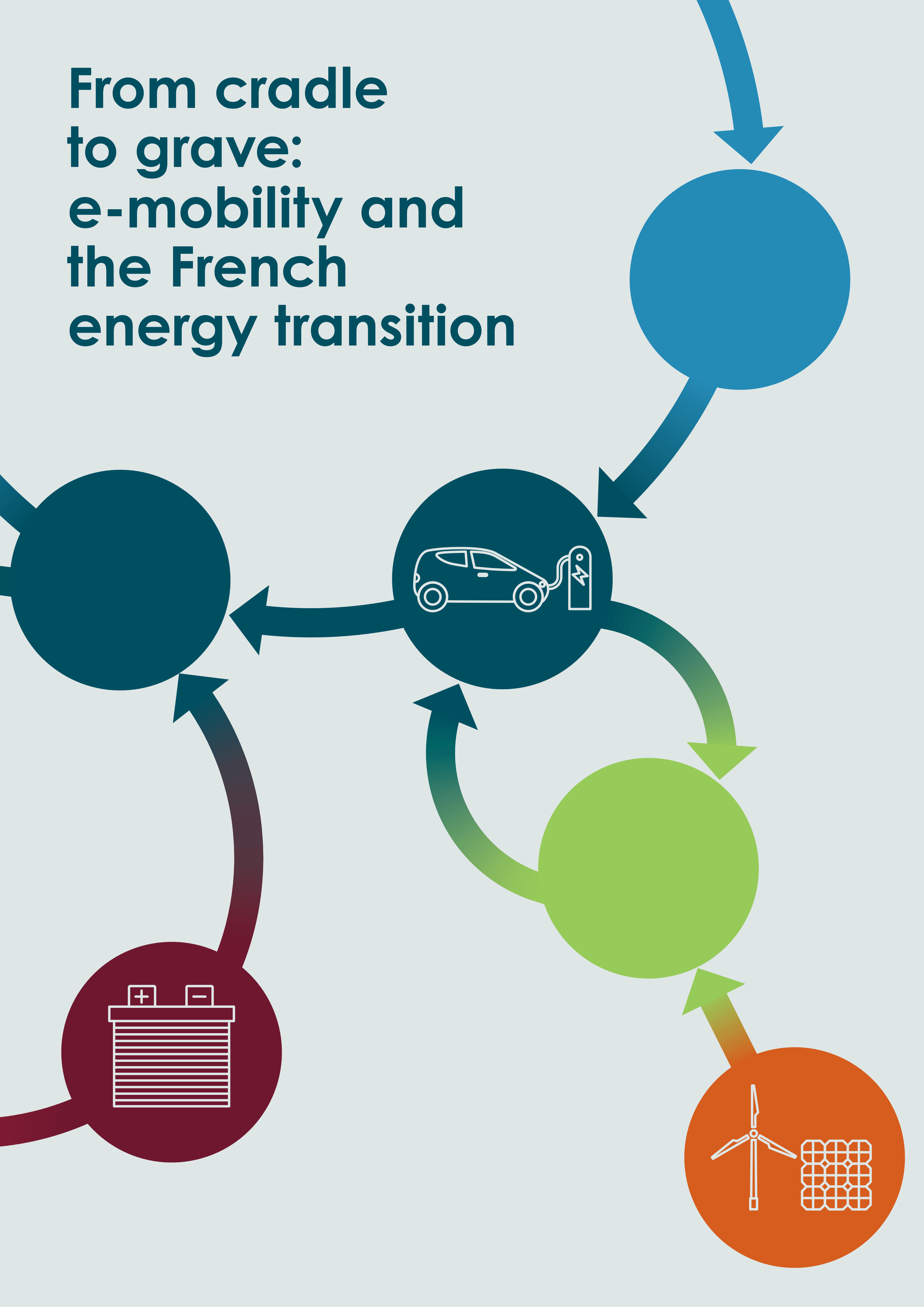
From cradle to grave: e-mobility and the French energy transition



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The information and conclusions in this report represent the vision of the working group and not necessarily that of the companies and organizations taken individually.

This is a summary in English of the technical report: **"Quelle contribution du véhicule électrique à la transition écologique en France ?"**, which can be downloaded at: https://europeanclimate.org/levehicule-electrique-dans-la-transition-ecologique-enfrance

Study carried out from May 2016
to November 2017.

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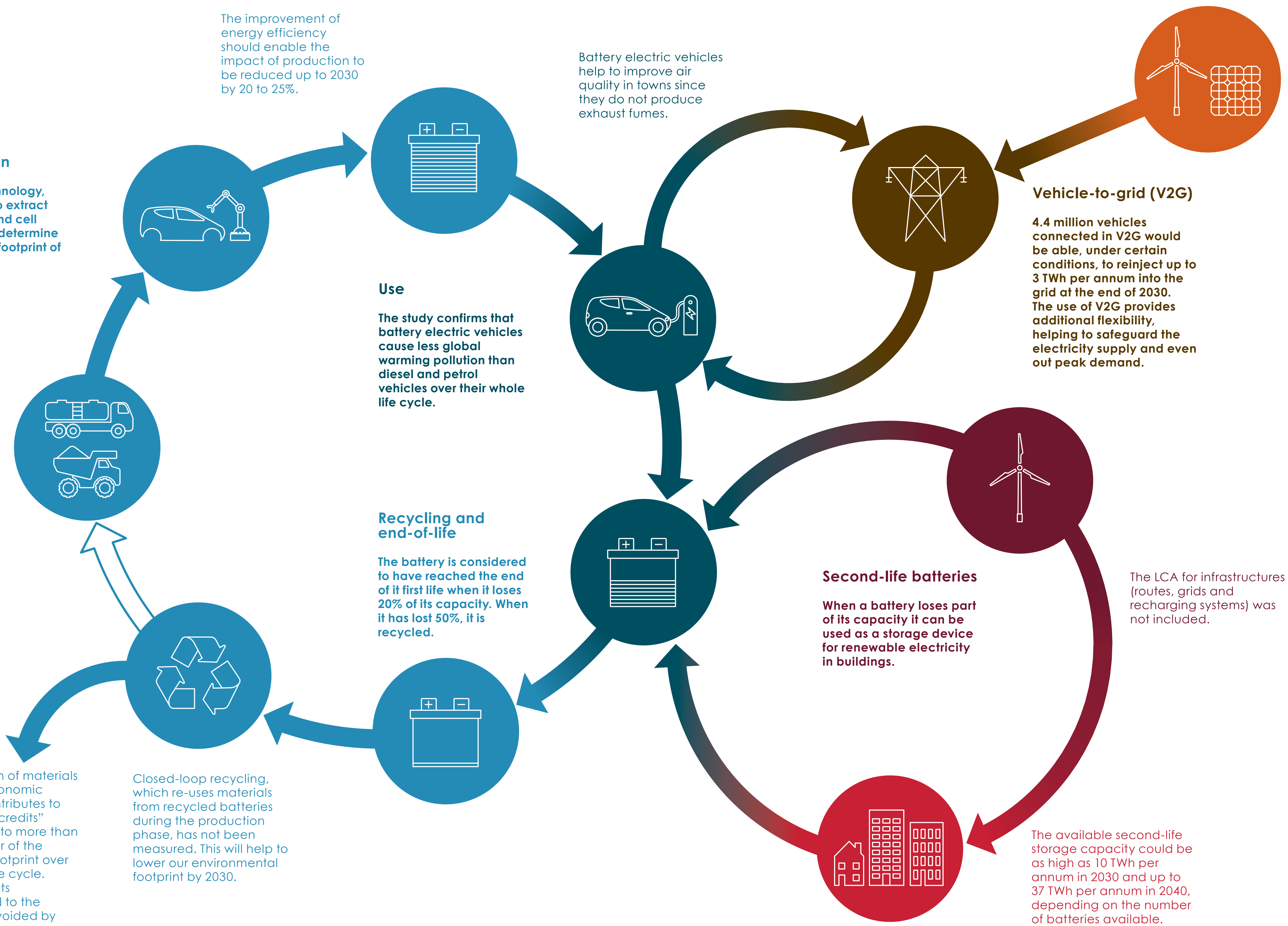


Production

Battery technology, processes to extract resources and cell production determine the carbon footprint of vehicles.

The improvement of energy efficiency should enable the impact of production to be reduced up to 2030 by 20 to 25%.

Use

The study confirms that battery electric vehicles cause less global warming pollution than diesel and petrol vehicles over their whole life cycle.

Battery electric vehicles help to improve air quality in towns since they do not produce exhaust fumes.

Vehicle-to-grid (V2G)

4.4 million vehicles connected in V2G would be able, under certain conditions, to reinject up to 3 TWh per annum into the grid at the end of 2030. The use of V2G provides additional flexibility, helping to safeguard the electricity supply and even out peak demand.

Battery electric vehicles are stakeholders in the electricity system. The composition of the electricity mix which powers these vehicles, the respective percentage of fossil, renewable and nuclear fuels, consumption levels and modalities for charging, all impact our environmental and climate footprint.

Second-life batteries

When a battery loses part of its capacity it can be used as a storage device for renewable electricity in buildings.

The LCA for infrastructures (routes, grids and recharging systems) was not included.

The available second-life storage capacity could be as high as 10 TWh per annum in 2030 and up to 37 TWh per annum in 2040, depending on the number of batteries available.

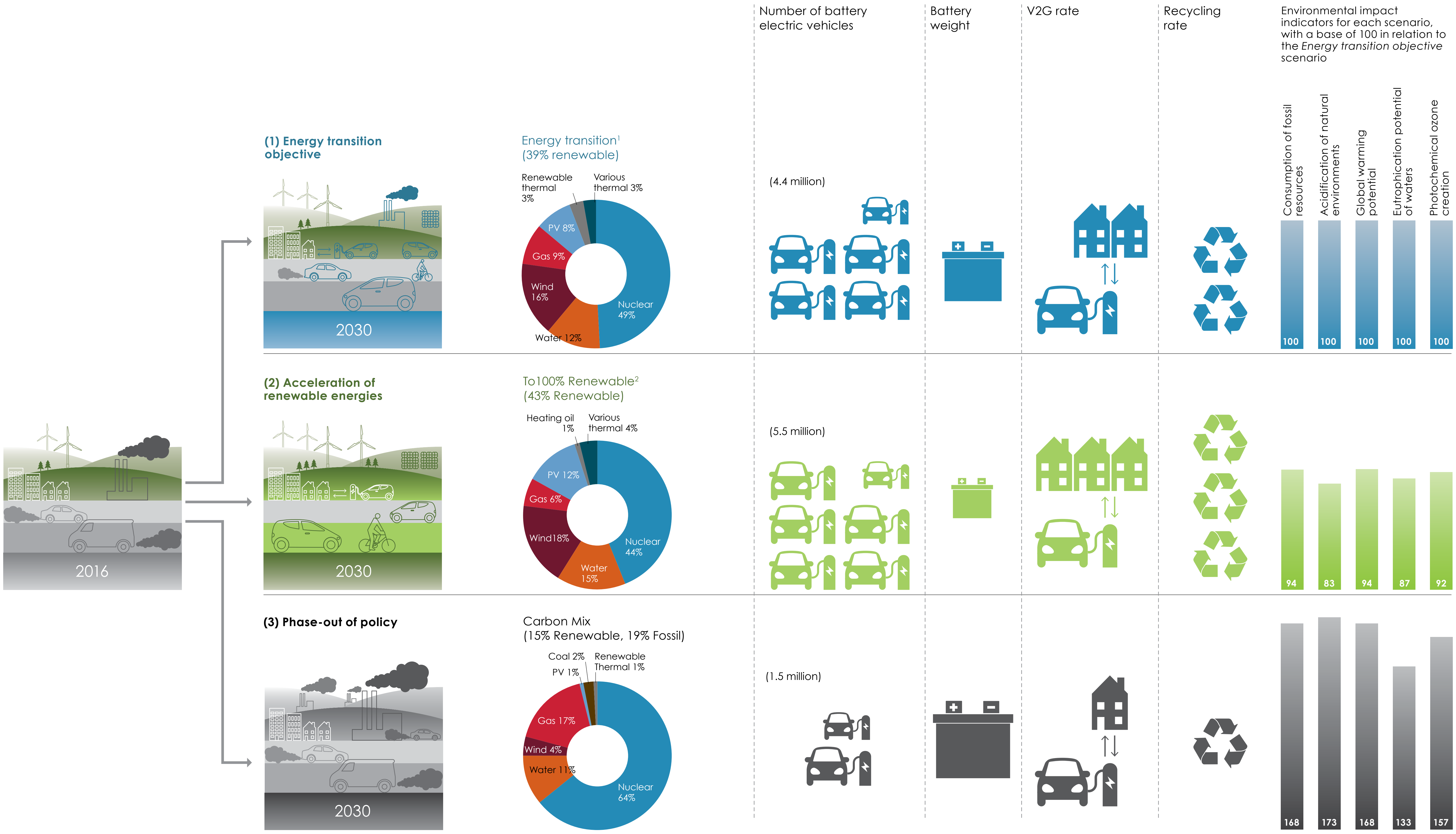
Recycling and end-of-life

The battery is considered to have reached the end of it first life when it loses 20% of its capacity. When it has lost 50%, it is recycled.

Closed-loop recycling, which re-uses materials from recycled batteries during the production phase, has not been measured. This will help to lower our environmental footprint by 2030.

Reutilisation of materials in other economic sectors contributes to "recycling credits" equivalent to more than one quarter of the vehicle's footprint over its whole life cycle. These credits correspond to the footprint avoided by other sectors.

Three contrasting scenarios of the utilisation of battery electric vehicles in France up to 2030



1 This study was carried out using the long-term data from RTE's Interim Report 2014 and from the Multiannual Energy Plan 2016, and is not based on simulations of the Interim Report 2017, since the latter was compiled after this study and was still being edited when this document was finalised.

2 Source: Ademe: Towards a 100% renewable mix in 2050

Summary

The climate plan launched by the French government in July 2017 set 2040 as the end of sales of petrol and diesel vehicles. This course is in line with the dynamic of Europe's fight against climate change and the imperative of reducing oil import dependency. Consequently, it is a matter of accelerating the transformation of mobility through the promotion of diversification of the means of transport and by accelerating the conversion of existing vehicles to alternative fuel vehicles. The deployment of battery electric vehicles is one of the priorities in this scenario.

The advantages of battery electric vehicles in reducing local air pollution, in particular in towns, are widely recognised today. In contrast, their contribution and the limits to their contribution to the fight against climate change, to the energy transition, and attainment of the objectives of the French Energy Transition for Green Growth Act (LTECV) of 2015 warrant clarification. The same applies to the reduction of environmental pollutants and pressure on natural resources. **From this perspective, we are presenting an analysis of the environmental and climate impacts of battery electric, plug-in hybrid and internal combustion engine vehicles over their whole life cycle.** This study enabled us to examine the risks and opportunities of "e-mobility" deployment in France up to 2030 within the framework of the ecological and energy transition.

The energy situation in France will have to change dramatically by 2030 – coal and oil-fired power stations will be shut down, the number of nuclear power stations will be cut, the development of renewable energies will be accelerated, energy consumption at all levels must be lowered, and energy production decentralised. There is a synergy between the developments beginning in the transport sector even now and the changes which France will see by 2030, and even more so by 2050.

Three scenarios for developing e-mobility up to 2030 have been drawn up:

(1) Energy transition objective
2) Acceleration of renewable energies
3) Phase-out of policy and the associated environmental risks.

Each of these visions highlights the environmental risks and opportunities related to developing batteries for battery electric cars and their production methods, recycling methods, as well as the electricity mix and its composition. The analysis is based on multiple criteria. It measures, throughout the life cycle of vehicles, the climate impact (global warming potential, expressed in t CO2–eq.), consumption of fossil resources (in MJ), acidification of natural environments (in SO2–eq.), eutrophication of waters (in kg P04–eq.), as well as photochemical ozone creation (in kg ethene eq.).

Each scenario also evaluates the opportunities opened up by the electricity storage functions which batteries offer. In fact, when a battery electric vehicle is parked and charging, it is able to export part of the electricity from the battery to the grid, in what is called vehicle-to-grid. These exchanges, at the scale of one vehicle and, more particularly, for a whole fleet, could help to relieve peaks in daytime and night-time electricity consumption. Battery electric vehicles can also help to manage overloads, voltage levels and mains frequency by absorbing the variable surplus produced by renewable energy systems, for example by photovoltaic panels or wind parks.

Once a battery installed in a battery electric vehicle has lost a major part of its initial charge (for example 20%), and hence its autonomy, it can be deployed for second-life utilisation. After reconditioning, it can be used to store renewable energy. This additional use of batteries and, more globally, the synergies between the electricity network and the mobility sector in France can open up new opportunities to accelerate the ecological transition. The time frame of the analysis, with 2030 as the cut-off, constitutes a milestone in achieving the objectives of the energy transition for 2050.

This study confirms that the environmental advantages of battery electric vehicles are intrinsically linked to the implementation of the ecological and energy transition. The types of impact of these vehicles on the climate and the environment vary depending on the electricity mix used in charging, and related external aspects (CO2 emissions, nuclear waste). The environmental advantages of battery electric vehicles in the fight against climate change are confirmed for 2016 and will be for 2030 if the objectives of the Energy Transition Act are achieved, scenario 1. They will be even greater in an ambitious scenario of developing renewables, scenario 2.

In a context of strong growth in the market for battery electric vehicles up to 2030, the reduction of the impact of the production stage is one of the conditions for sustainability of the sector. The four main levers identified to manage and reduce this impact can be found at the level of mineral extraction, efficiency of production methods, battery development (efficiency, weight, use) and the promotion of recycling practices.

Furthermore, the environmental advantages of battery electric vehicles can be increased, as shown in this analysis, by maximising the use of batteries for mobility (car-sharing and increasing mileage) and by using their storage function to provide services to the electricity network (V2G). The analysis enabled us to measure the additional benefit of these services provided to the electricity network in each of the three scenarios proposed.

Finally, the study highlights the use of second-life batteries for storing electricity, especially from a renewable source. This type of use is a means to optimise natural resources and an instrument to accelerate the energy transition beyond 2030. The number of e-vehicles in 2030 is in fact considered as a milestone for 2050. The level of targets for the spread of e-mobility in France will define the storage potential available in 2040 and beyond.

Together with controlling energy consumption (efficiency and restraint) and intelligent management of charging and development of storage capacities, e-mobility could go hand in hand with the energy transition, development of renewables, and a progressive exit from fossil fuels and nuclear energy. To bring about this pioneering process, the stakeholders must not hesitate to open a space for reflection, dialogue and collaboration between the world of mobility and that of energy.

In order to carry out this study, the Foundation pour la Nature et l'Homme and the European Climate Foundation gathered together NGOs, as well as institutional and private players. The automotive sector was represented by Renault, the e-mobility ecosystem by Avere-France, and battery manufacturers by Saft. Ademe and RTE brought their expertise from the field of energy and management of electricity networks. Five NGOs also participated: Réseau Action Climat France, WWF France, Réseau pour la transition énergétique (CLER), Foundation pour la Nature et l'Homme and, finally, the European Climate Foundation. The forecast for 2030 was conducted by Carbone 4. In order to validate the reliability of the methodology used, the plausibility of results and the transparency of the analysis, four independent experts carried out a critical review of the study.[3]

3 The report of the critical review can be found in the annex to the technical report.

Climate and energy: the advantages of e-mobility in the energy transition

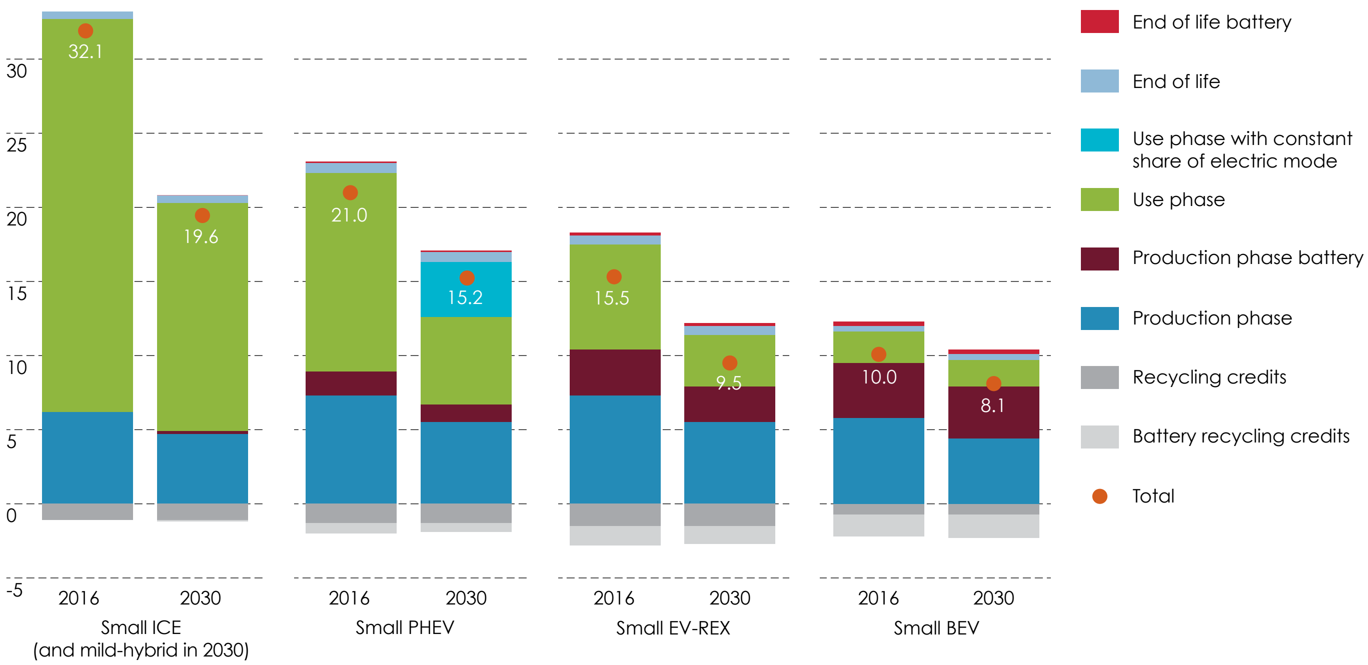


Figure 1

Global warming potential: 2016-2030 results compared for the small car sector (t CO2-eq.)

The environmental advantages of battery electric vehicles are intrinsically linked to the implementation of the ecological and energy transition. Taking into account the various stages in the life cycle, “from cradle to grave”, the contribution of small electric cars and electric saloon cars charged today in France to climate change is 2 to 3 times less than that of Internal Combustion Engine vehicles. This advantage will be maintained in 2030 if the objectives of the French Energy Transition Law are achieved, and will be even greater if France extends its objectives to develop renewable energy and commits to a scenario that is 100% renewable.

Transport is a key sector in the energy transition. It is also the only sector in France where greenhouse gas emissions have risen since 1990. It represents around 30% of greenhouse gas emissions in France. It is 94% dependant on fossil fuels. It is, therefore, essential to accelerate the transition in transport by controlling consumption, a modal shift, energy efficiency, and electrification based on renewable energy.

The climate impact of a battery electric vehicle occurs mainly during the production phase (75%). The associated greenhouse gas emissions are due in part to car manufacture (bodywork, steel production, plastics production) and in part to production of batteries. In the latter, emissions ensue from the energy consumed to extract, refine and transform the mineral resources used in battery cell production (anodes and cathodes).

The other decisive factor in the environmental impact of battery electric vehicles concerns the modalities of electricity production used for driving, and therefore the associated external factors (emission of pollutants, greenhouse gases, radioactive waste). If the electricity which charges the battery was produced in power plants fired by fossil and/or fissile fuels, the environmental impact of the vehicle will be higher. Inversely, an electricity mix based largely on renewable energy will reduce the environmental impact of an electric car.

The carbon footprint of battery electric vehicles varies especially according to the carbon content of the electricity consumed, and therefore the composition of the mix. The carbon content is defined by an emission factor that can vary by several dozens of g CO2/km for electricity from a renewable source (78 g CO2/km for solar, 22 g CO2/km for wind) to 430 g CO2/km for gas or more than 1kg of CO2 for coal. The parameters which impact the composition of the electricity mix at a given moment must therefore be taken into account. These include, for example, the times at which the vehicle is charged or even the exterior temperature. Shutting down coal-fired power plants, scheduled for 2023, and the installation of new

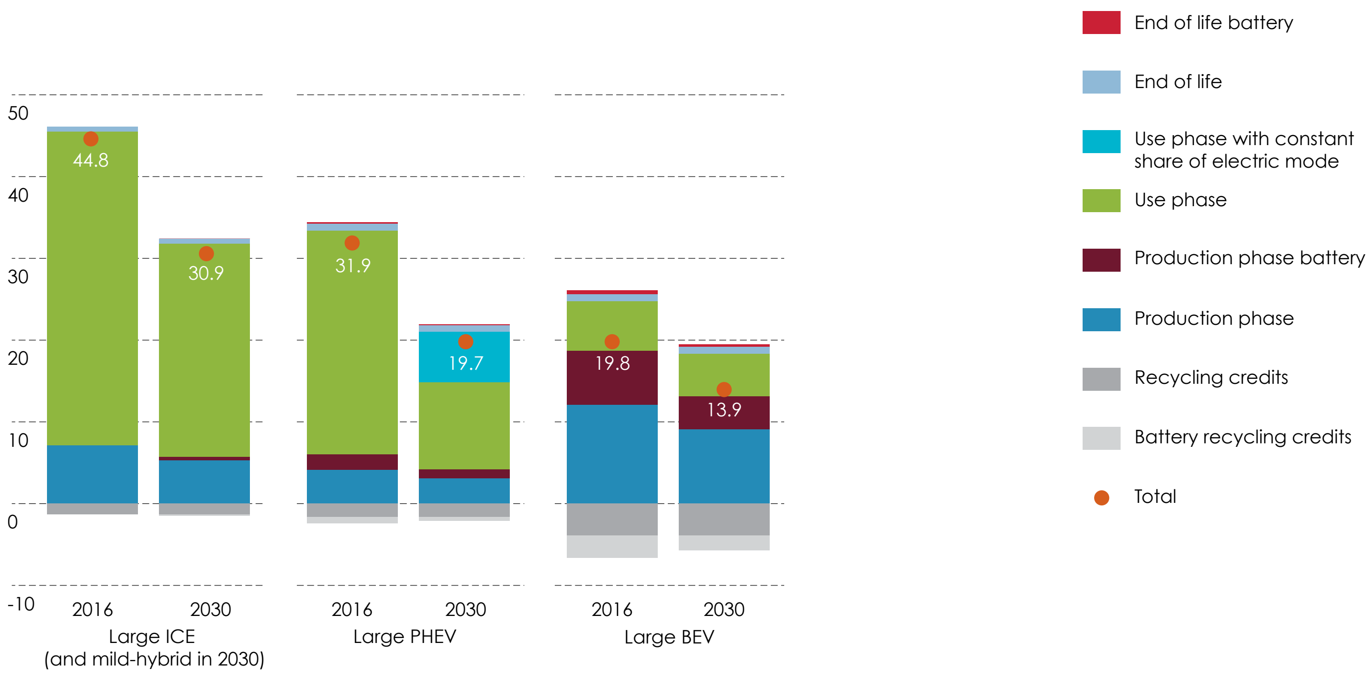


Figure 2

Global warming potential: 2016-2030 results compared for the saloon car sector (t CO2–eq.)

renewable energy capacities to replace nuclear plants or those fired by fossil fuels in France, as well as controlling and lowering electricity consumption, will enable this already limited impact to be lowered again in the utilisation phase.

In 2016, according to this life cycle analysis, a small electric car emitted on average 63% less greenhouse gases than a petrol car (12 t CO2–eq. and 33 t CO2–eq.) without taking into account the recycling credits, and 70% less when including these credits (10 t CO2–eq. and 32 t CO2–eq.). An electric saloon car emitted on average 44% less greenhouse gases than the same model of diesel car (26 t CO2–eq. and 46 t CO2–eq.) without taking into account recycling credits, and 57% less when including these credits (19 t CO2–eq. and 45 t CO2–eq.).

The study shows how the evolution of the electricity mix in France up to 2030 could make the emissions related to the use of a battery electric vehicle vary. If France should not achieve its energy transition objectives for 2030, and increasingly resorts to fossil energy (to the tune of 19% of the electricity mix), the consumption of fossil resources and vehicles' contribution to climate change (over their whole life cycle) will increase by around 20%, while their potential for acidification of natural environments will rise by 13%. Nevertheless, when the percentage of renewable energy increases from 39% to 43% in electricity consumption, all types of impact of battery electric vehicles and plug-in hybrid vehicles will drop by 5% on average for small cars and saloons.

Therefore, in scenario 1, *Energy transition objective,* the carbon footprint of a 100% electric small car used for 10 years, and over its whole life cycle, will remain relatively stable, at 10.4 t CO2–eq. (Figure 2). Regarding saloons, in this scenario they will see their carbon footprint drop, from 26 t CO2–eq. in 2016 to 19 t CO2–eq. in 2030 (Figure 3). This scenario includes a baseline scenario for the capacity and efficiency of batteries, mild-hybridisation of ICE vehicles, and an increase in the energy efficiency of production methods.

In scenario 2, *Acceleration renewable energies,* the carbon footprint of a small electric car, for example, could be reduced to 6 t CO2-eq. over the whole of its life cycle (including recycling credits). This scenario is based on a reduction in the weight of batteries and hence of the quantity of materials used, as well as a significant recycling percentage of batteries (85%).

In Scenario 3, *Phase-out policy,* the carbon footprint of a BEV saloon will increase by 2.4 t CO2-eq. to reach 27 t CO2-eq. by 2030.

The carbon footprint of plug-in hybrid vehicles, halfway between internal combustion engines and battery electric vehicles, is itself especially sensitive to the amount of miles travelled in electric mode in relation to the amount travelled using the ICE.

Air pollution

When moving, a battery electric vehicle differs from an ICE vehicle in that it does not produce polluting exhaust emissions (nitrogen dioxides and particles) and **hence means an improvement in the quality of air in an urban environment.** The phenomenon of tyre abrasion, road surfaces or brakes, remains. Nevertheless, **the reduction in emissions is significant and represents an undeniable advantage for the quality of air, especially in an urban environment.** According to the study published in 2015 "En route pour un transport durable" (Fuelling France), with 4.4 million battery electric vehicles in 2030 (including PHEV), exhaust emissions of atmospheric pollutants from light vehicles in France could be reduced by approximately 72% for NOx and 92% for fine particles (PM10<).

Issues of the circular economy for the battery electric vehicle sector

The production stage of electric vehicles, including batteries, is responsible for a significant part of the environmental impact. On average, for the vehicles studied, 75% of their contribution to climate change or their potential for acidification of natural environments are related to the upstream phase. In a period of major growth in the battery electric vehicle market up to 2030, the four main levers identified to manage and reduce this impact can be found at the level of 1) mineral extraction, 2) efficiency of production methods, 3) development of batteries in terms of efficiency, weight and use, and 4) promotion of recycling practices.

Private, battery electric, or ICE vehicles have a significant environmental impact due to the raw materials used in their production (without counting their utilisation). From this perspective, the conventional automotive sector has optimised production processes and has achieved material recycling rates of up to 85%, with repurposing and direct reutilisation of incoming materials. The energy efficiency savings confirmed over the last fifteen years are equivalent to 2% per annum. For electric vehicles, the battery is an additional production loop which must be taken into consideration.

Battery production has an impact firstly on the lands where mineral resources (lithium, cobalt, nickel, manganese) are mined and processed. Today these activities are mainly located in developing countries. Cells are mainly transformed nowadays in Asia. The potential for acidification of natural environments and the eutrophication of waters are the two indicators used in this study to measure the impact on ecosystems. These phenomena bring about the impoverishment of natural environments and affect flora and fauna at a local or regional scale. In 2016 battery electric vehicle represented between 8 and 15% of the total acidification burden of an average European inhabitant, depending on the vehicle type and segment. The consequences of battery electric vehicle production on natural environments must therefore be looked at carefully in a situation where production is increasing significantly.

The advantages of energy efficiency have a direct impact on lowering the environmental footprint of vehicles. Following the trend observed by manufacturers for over ten years, up to a 25% increase in the energy efficiency of production methods could be contemplated by 2030.

The key role of batteries

Although difficult to predict, it is probable that the evolution of batteries between the present and 2030 will follow both trends observed, namely an increase in battery range and efficiency, while tracing the different paths between vehicle models. This trend could in fact be accelerated by a high demand for affordable vehicles with limited range (in urban environments) on the one hand, and on the other by a demand for high-performance vehicles with greater range, but more expensive (saloons). The current technological choices which define the types of batteries in the market in 10-15 years and beyond will determine the level of mobilisation of natural resources and the types of impact associated with the transformation of raw materials.

This analysis therefore compares three paths for the evolution of batteries. The study explores a range between 50 kWh for small BEV cars and 90 kWh for BEV saloons. According to a second hypothesis of maximum growth, the capacity of battery packs would increase up to 60 kWh for small EV cars and 120 kWh for EV saloons. Finally, according to a hypothesis of a "split" towards smaller and more compact batteries, the available capacities would lie between 30 and 60 kWh.

It follows that maximum growth in capacity, together with greater range and greater weight of batteries, will increase the impact of small cars on acidification of natural environments up to 2030. For plug-in hybrid vehicles (PHEV) this impact will increase by 20-30%. According to the growth path taken, the impact on water (eutrophication) will also rise, by more than 20% for PHEV. On the other hand, the downsizing hypothesis for batteries offers an opportunity to reduce the environmental impact of batteries on water, natural environments, and the climate. If the weight of batteries should drop, the quantity of materials mined and then processed would drop. This means the associated impact would also be reduced.

Recycling batteries

Recycling battery components is an important tool to reduce the environmental footprint of a vehicle. Since 2006, European legislation requires automotive companies to recycle at least 50% of the weight of lithium-ion[4] batteries. Mineral resources are recycled (cobalt, manganese, nickel, copper, lithium), even if they are not re-used in a closed circuit, for the production of new batteries. The effect of recycling is taken into account in this analysis as the impact avoided in other sectors, such as construction or the chemical industry. It is described as "recycling credits". These equate to between one quarter and one third of the vehicle's impact over its whole life cycle.

The increase in the mandatory recycling rate would allow the range of materials recovered to be increased (plastics and aluminium, for example). It would also reduce the impact on natural environments and air oxidation through ozone (creation of photochemical ozone). Finally, closed-loop recycling can offer a solution both for the criticality of certain mineral resources. Although not evaluated in this study, the economic and strategic dependence of the automotive sector on these materials is a cause for concern. In fact, the question of mineral resources means that the battery production sector has to be regarded specifically from the economic and geostrategic point of view, as well as corporate social responsibility.

Furthermore, the environmental advantages of battery electric vehicles can be increased, as shown in this analysis, by maximising the use of batteries for mobility (car-sharing and increasing mileage). Batteries produced for mobility do in fact have sufficient resistance during their service life for more intensive use. Our baseline assumptions are conservative.

The variation in mileage in fact has a limited effect on the carbon footprint of battery electric vehicles. Hence for 100% battery electric vehicles, a 20% increase in mileage translates to a rise of 5% in the total impact of small cars, and 8% for saloons. A sensitivity analysis was carried out to evaluate the impact in cases where the battery would have to be replaced after greater mileage. An increase of 60% of miles travelled will potentially lead to a significant increase in impact, more than 30% as a result of the battery being replaced. Multiplication of mileage in the same proportions for ICE vehicles considered in this analysis implies a doubling of the carbon footprint. The advantage of a battery electric vehicle is therefore maintained when taking emissions into account caused by battery production.

4 Directive 2006/66/EC of the European Parliament and Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC defines in Annex III – Part B minimum recycling efficiencies: "recycling of at least 50% by average weight of other waste batteries and accumulators."


@Saft

Vehicle-to-grid, an additional aspect of flexibility for the electricity system

E-mobility creates challenges and opportunities for the French electricity system. The first is that of controlling electricity consumption. It offers supplementary means of including flexibility in the electricity system, especially through V2G.

Linked to controlling energy consumption (efficiency and restraint), to intelligent management of charging, and to developing storage capacities, e-mobility can play a role in the energy transition and contribute to the development of renewable energy and to a progressive withdrawal from fossil fuels and nuclear energy.

We have evaluated the potential of smart charging in order to limit the additional consumption of electricity and production of CO2 emissions. In this scenario, charging in the morning and evening during peak demand is managed and spread over working hours, or postponed to night hours (Figure 4). It should be noted that the use of smart networks is sensitive to battery charging and discharging practices and methods by vehicle owners and by fleet managers. In certain cases, these practices can mean the service life of batteries can vary. Charging and discharging behaviour, for example by maintaining a minimum charge in the battery, will limit these types of impact.

The study also takes account of the services that electric vehicles can provide to the electricity system and to the integration of renewable energy through bi-directional exchange, called vehicle-to-grid. V2G is when vehicles re-inject electricity into the network in response to variability in renewable energy production (with a 10% loss of energy). Although it is difficult to anticipate the speed of deployment of this type of service, as well as the modalities for charging and the capacity of the network to absorb these energy flows,

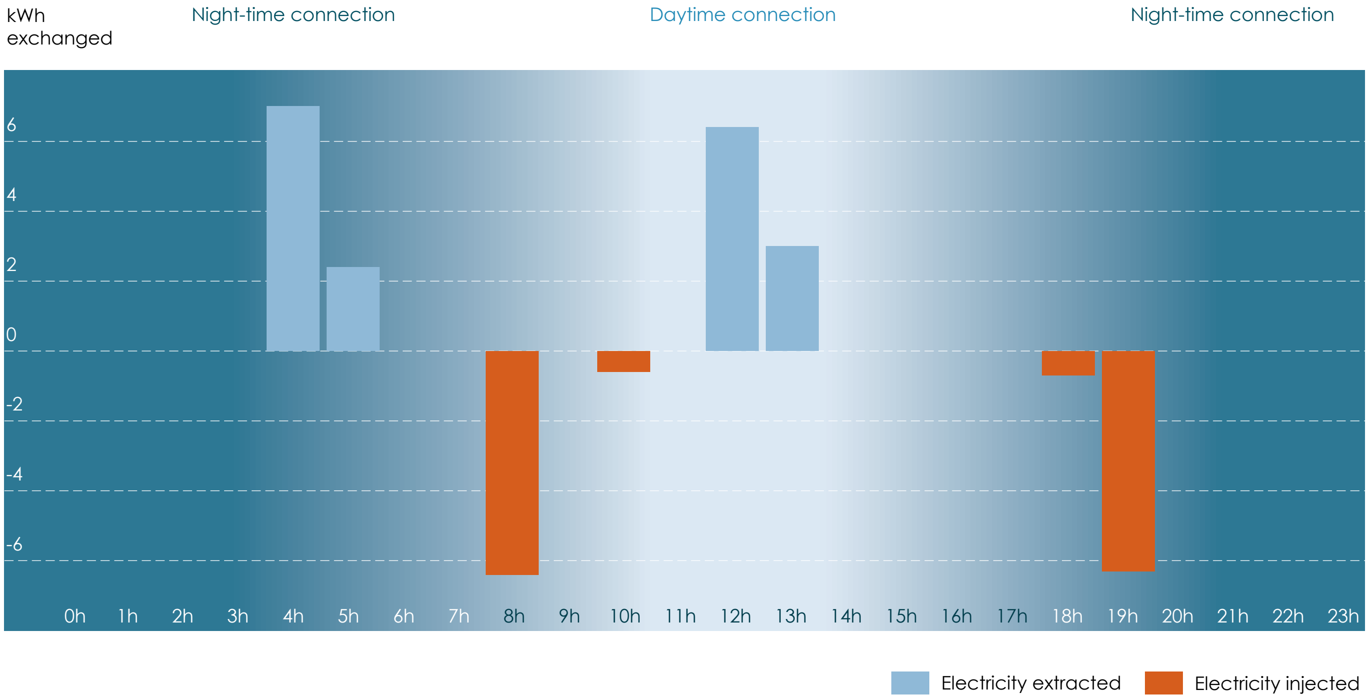


Figure 3

Bi-directional exchange of electricity (V2G) of a small electric car during a winter's day.

This diagram shows V2G use for a small BEV car in a week in winter in scenario 1, Energy transition objective. It shows that the vehicle supports the electric system when it arrives at its charging point, whether early evening (18.00 and 19.00) or in the morning after being driven (8.00) when it injects around 6 kWh. The vehicle recharges when fewer demands are made on the electricity system, between 12.00 and 14.00, and between 4.00 and 6.00 in the case in question.

the initial feedback indicates a potential to relieve peak demand by day and by night, managing overloads, voltage levels and frequency, while absorbing the surplus energy produced from photovoltaic panels or wind turbines.

These services make sense when measured on the scale of several million vehicles. In scenario 1 (Energy transition objective) the objectives of the French Energy Transition Law are achieved and 4.4 million battery electric vehicles are on the road. If all charging is "natural" (i.e. not managed), electricity consumption is estimated at between 11.3 TWh and 12.4 TWh per annum, including a loss rate of 10% during charging. As soon as charging battery electric vehicles can be managed (carried out earlier or later), it is possible to limit the recourse to fossil energy and for vehicles to provide services to the electricity system by giving it flexibility. In scenario 1, 40% of charging is done using smart charging and 30% of vehicles use bi-directional exchange in V2G. Consumption, which can in this case be delayed to outside peak demand over the year, would therefore account for more than 7 TWh per annum. If we consider the benefits of V2G on its own and in the same conditions, this is almost 3 TWh per annum that can be re-injected into the network.

This energy could be used to safeguard supply and replace fossil energy sources used as a reserve of primary and secondary energy. This is a fast and flexible way of managing contingencies in the electricity system.

In addition, this analysis of potential allows the "reserve base" of battery electric vehicles to be estimated. In fact, the capacity of batteries is clearly greater than the distance of journeys made by cars during the day. If, after a day of driving around, battery electric cars are connected to a charging point at home, they retain residual power in their battery. This battery can be used to supplement electricity generation if there is high demand on the national grid. Assuming 4.4 million vehicles, the study estimates a maximum potential in 2030 of nearly 45 GWh in the time slot 18.00-20.00 on an average winter's day in France, of which a part can be mobilised very quickly. Battery electric vehicles thus appear to give an extra measure

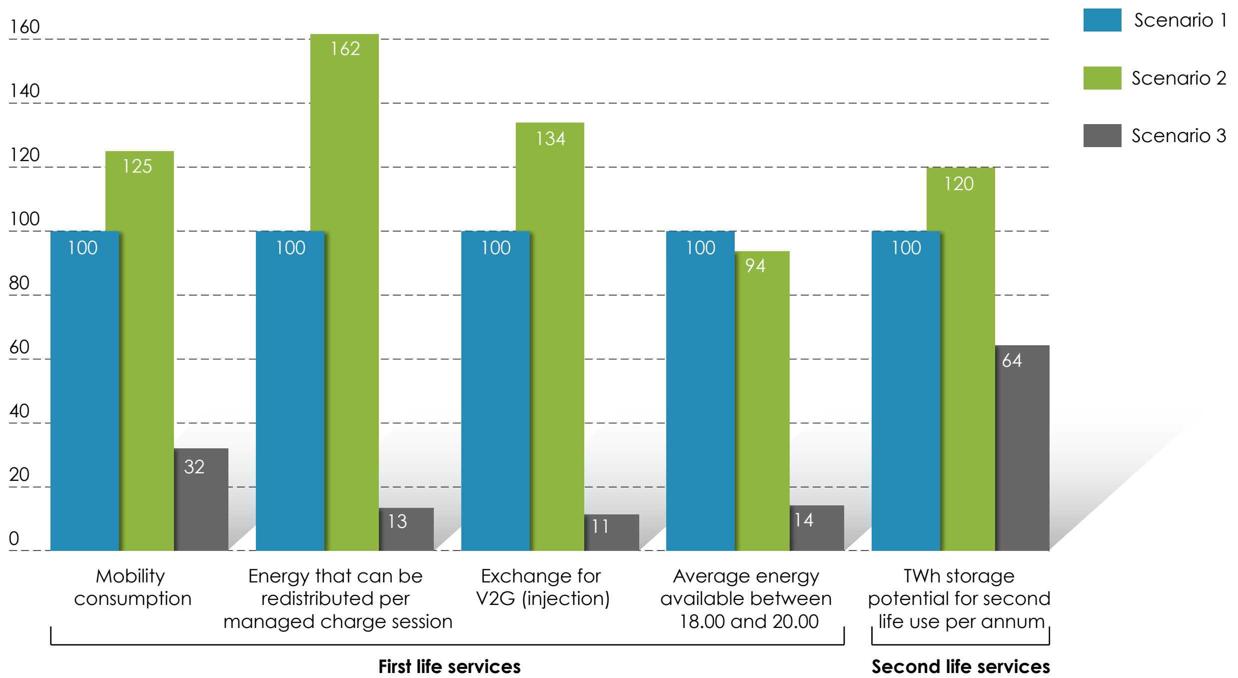


Figure 4

Potential for services offered to the electricity system in the different scenarios (base of 100)

of flexibility to balance the electricity system and to avoid possible cuts.

This is a significant quantity of energy, given that consumption varies between 60 and 80 GWh per hour on a winter's day, for example. This maximum reserve potential includes all the residual energy in vehicles (without impacting the minimum charge of the battery). That is why it is a "reserve potential", all of which can be used if there is strong demand, which can only be mobilised at certain times of the year and at a speed that cannot exceed the unit capacity of charging points. It is reasonable to estimate that only a fraction of this potential (for example 10%) would be extracted if needed by network operators.

A comparison of the scenarios allows us to identify the conditions necessary for the bi-directional exchange of electricity, or V2G. The conditions for the development of V2G are:

- It must reach a critical mass.
- V2G must optimise carbon-intensity of the energy mix.
- Must be done in a way that meets drivers' needs.

Only the scenarios which achieve the objectives of the Energy Transition Law will allow a significant level of services to be offered to the electricity system, in particular due to V2G. An insufficient level of deployment of battery electric vehicles and dedicated infrastructure would not allow recourse to the secondary function of batteries and would mean a shortfall when trying to promote the energy transition in France.

@Volker Witt

Second-life batteries, a means to store renewable energy

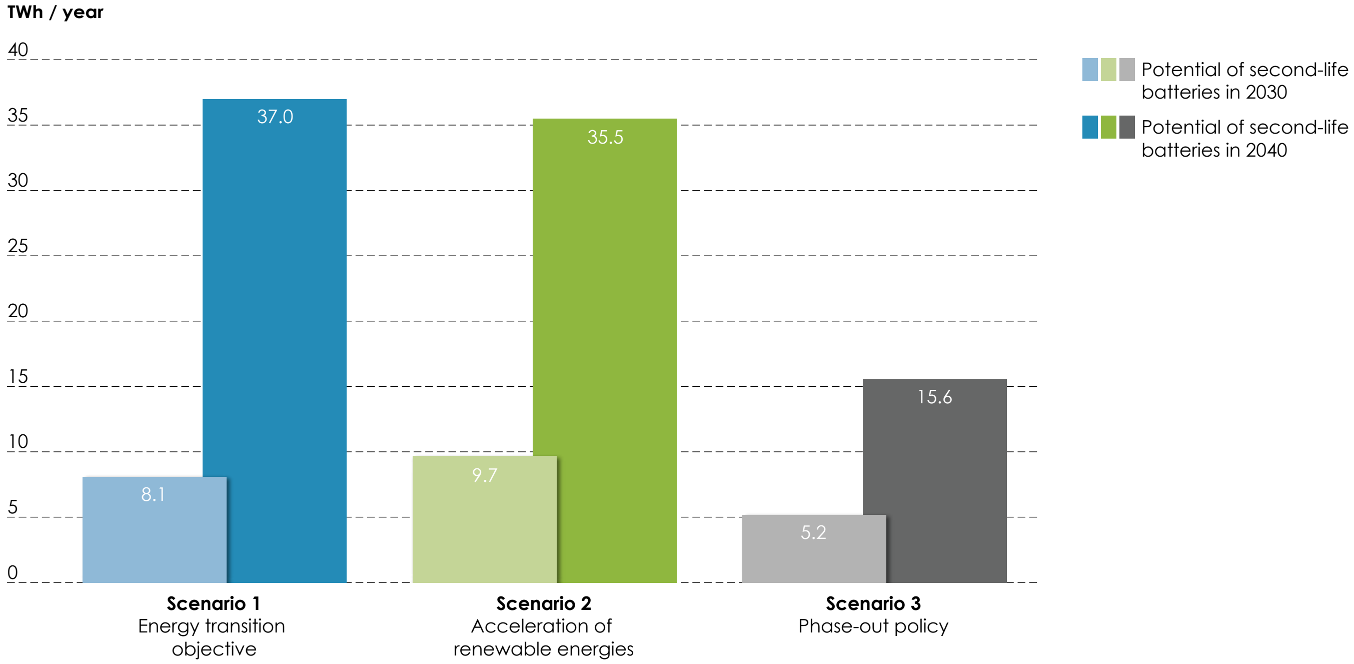


Figure 5

Storage capacity and reinjection during second life compared between the scenarios

When a battery loses a significant part of its capacity it can be reconditioned and used as a storage device for renewable electricity in buildings, for example. Renewable energy can therefore be stored when a surplus is available and then reinjected when demand is high, or it can be used for own use. Therefore second life prolongs the use of batteries considerably, beyond their first life use in mobility.

The study assumes a duration of 5 years for second life use, having taken the results of ongoing tests into consideration. It is important to note that this period is sensitive to the use made of batteries, to charging and discharging patterns.

Furthermore, the main objective was to offer an initial evaluation of the capacities which a significant volume of second-life batteries could provide. The challenge of collection, the impact of the reconditioning phase, and the integration of a new system to manage batteries have not been examined here. They are identified as key factors to consider in prolonging second life use.

The number of second-life batteries effectively in use in 2030 evaluated in the study is based on the number of battery electric vehicles on the road in 2020. Based on a stock of batteries of around 960,000 units[5], this would mean a storage capacity of 8 TWh per annum. If all batteries from electric vehicles in 2030 were used for stationary storage 10 years after they were brought to market (4.4 million second-life batteries), the storage capacity would be around 37 TWh per annum.

Storage capacity varies between the scenarios to between 5 and 10 TWh per annum in 2030. In 2040, on the basis of a complete daily cycle of a battery, the potential for storage and reinjection are of the order of 15 to 37 TWh per annum. Although the situation in 2030 varies only slightly between the three scenarios (between 5.2 and 9.1 TWh), in the future these scenarios will be markedly different for 2040 and 2050. From this perspective, 2030 should be seen as a milestone in the energy transition up to 2050. The deployment pattern for battery electric vehicles will play a major role in the deployment of this use of storage.

5 This figure corresponds to the number of electric vehicles (BEV and PHEV) on the road in 2020, whose batteries will start their second-life utilisation in 2030. Source: Stratégie nationale de mobilité propre, PPE (National strategy for clean mobility, Multiannual energy plan) 2016. (See Chapter Methodology)

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Summary of impact indicators

This life cycle analysis is based on multiple criteria. It measures the following types of impact throughout the life cycle of vehicles:

Abiotic Depletion
Consumption of fossil resources, expressed in MJ. Quantity of fossil energy consumed over the life cycle of a vehicle.

Acidification Potential on Ecosystems
Acidification of natural environments, expressed in kg SO_2–eq. Acidification of ecosystems caused by the combustion of fossil fuels.

Global Warming Potential
Global warming potential, expressed in t CO_2–eq. Contribution of greenhouse gases to global warming.

Eutrophication Potential on Water
Eutrophication potential of waters, expressed in kg PO_4–eq. Excessive injection of phosphate or nitrogen products which encourage the rapid growth of algae.

Photochemical Ozone Creation Potential
The creation of a photochemical ozone, expressed in kg C_2H_4–eq. Transformation of atmospheric pollutants into ozone and other oxidising compounds.

Summary of abbreviations for vehicles

ICE: Internal Combustion Engine Vehicle

PHEV: Plug-in Hybrid Vehicle

EV-REX: Electric Vehicle Range Extender

BEV: Battery Electric Vehicle

European Climate Foundation (ECF)

The European Climate Foundation (ECF) – a 'foundation of foundations' – was established in early 2008 as a major philanthropic initiative to help Europe foster the development of a low-carbon society and play an even stronger international leadership role to mitigate climate change.

Fondation Pour La Nature Et L'homme (FNH)

Founded in 1990 by Nicolas Hulot, Fondation pour la Nature et l'Homme is now chaired by Audrey Pulvar. Recognized as a public utility, non political and non-denominational, FNH works for a world of equality and solidarity that respects Nature and human well-being. Its mission is to work towards a fairer, more united world in the respect of nature and well-being of mankind. The foundation is committed to accelerating individual and collective mind shifts towards an ecological transition of our societies. We believe that ecology should not be a topic amongst many others but instead be placed at the core of of both public and private action.

The results of the study clarify what is at stake in "e-mobility" deployment within the framework of the ecological and energy transition. They confirm the interest of an integrated vision of what is at stake regarding the environment, climate, water, soil, natural environments and resources in a mobility system that is undergoing total transformation. The scenarios encourage a special focus on coherence between the energy transition and e-mobility deployment. Finally, this study could encourage greater reflection on the transition to "clean" transport, new uses of vehicles and mobility service models, encouraging industry to take responsibility from mining minerals to recycling and developing "smart networks".