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Editorial

Why the Development of Internal Combustion Engines Is Still Necessary to Fight against Global Climate Change from the Perspective of Transportation

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Internal combustion engines (ICE) are the main propulsion systems in road transport. In mid-2017, Serrano [1] referred to the impossibility of replacing them as the power plant in most vehicles. Nowadays, this statement is true even when considering the best growth scenario for all-electric and hybrid vehicles. The arguments supporting this position consider the growing demand for transport, the strong development of cleaner and more efficient ICEs [2,3], the availability of fossil fuels, and the high energy density of said conventional fuels. Overall, there seems to be strong arguments to support the medium-long-term viability of ICEs as the predominant power plant for road transport applications. However, the situation has changed dramatically in the last few years. The media and other market players are claiming the death of ICEs in the mid-term [4]. Politicians from several G7 countries, such as France, Spain, and the United Kingdom, have announced the prohibition of ICEs in their markets [5], in some cases, as early as 2040. Large cities, such London, Paris, Madrid, and Berlin, are also considering severe limits to ICE-powered vehicles. What is the analysis that can be made from this new situation?

1. What Is the Problem with ICE (Internal Combustion Engines)?

The media's arguments against ICEs range from the need to reduce CO_2 emissions (global warming) to the need to improve the air quality in cities (NOx and particulate matter emissions).

Much of this debate about the future of ICEs has arisen from the Dieselgate scandal [6,7]. A horrible wrong decision from a management and engineering point of view at a specific time and place has generated a worldwide butterfly effect in the automotive industry. However, making the problem a virtue, Dieselgate has forced new regulations to obtain much more efficient and cleaner ICEs [8–11].

As commonly takes place, old and lax pollutant regulations have now resulted in a pendular effect toward radically contrary positions, delighting the media and generating excessive political reactions without a clear scientific basis. All this is reflected in the look to publish a sufficiently popular or good news novelty. We could define the situation as energy populism. Although new regulations that force ICE technology to be more environmentally friendly must always be welcome, prohibitions motivated by a poor diagnosis of the situation will not help at all, neither to improve air quality nor to mitigate global warming.

2. What Is the Problem with Electric Vehicles?

What should be the alternative to the current ICE in the mid-to-long term? Combining the pendulum effect of public opinion with the excellent marketing of new actors in the passenger car sector, a confusion cocktail is served for the media. After all, one might ask if the use of the conventional propulsive systems over 120 years was the right path. How can such an old concept be innovative?

How can the ICE be great and technologically advanced at burning fossil fuels? An easy but wrong conclusion comes without the need of reflection: Let us welcome "new electric motors and batteries" in zero-emission cars!

The bad news is that energy is neither created nor destroyed, only transformed. Electric motors and batteries are not new, nor are they clean and, in general, are not free from problems. One can directly identify two relevant problems.

The first problem is that vehicle propulsion involves energy transformations and the electric motor does not use a primary energy source but an energy vector. Although public opinion has a clear idea of how some processes like friction can negatively affect transport applications, the understanding of the impact of the second law of thermodynamics is limited. The problem is that electricity must be produced, most usually from non-renewable energy sources, which equals around 60% in energy losses, and then transported, which adds 20% of additional losses. Unfortunately, renewable sources are barely 10% of the global energy mix, as observed in Figure 1 [12] without a medium-term forecast of significant increase.

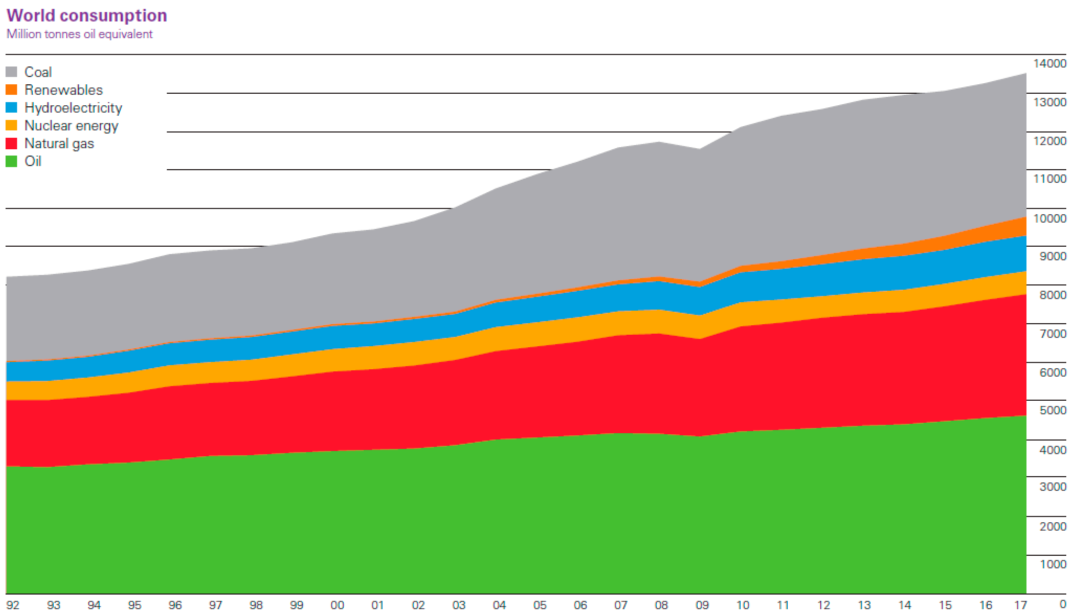

Figure 1. Evolution of world energy consumption by origin during the last 25 years [12].

In some countries like the USA, China, Russia, Poland, South Korea, or Germany, fossil fuels, including a good percentage of coal, remain the largest source of energy as a raw material for electricity production. In a first approach, the only G8 country with real alternatives to CO_2-emitting technologies is France due to its continued commitment with nuclear energy. Therefore, with the current energy mix and with an analysis of the complete life cycle, the so-called analysis from the cradle to the grave, the alternative to electric motors will not eliminate global CO_2 emissions.

On this concern, Figure 2 [13] which takes the data from the cradle to the grave analysis elaborated by the JEC—Joint Research Centre-EUCAR-CONCAWE collaboration [13] effectively shows how with the European electricity production mix the shift to battery electric vehicles (BEVs) would reduce but not remove CO_2 emissions. The reduction of the EU electricity mix is estimated as 40 gCO_2/km (from 210 to 170 gCO_2/km) in a total shift from ICEs to BEVs. However, the European Union reaches 35% of the mix between renewable and hydraulic energy sources [12], while worldwide, it is just 10% (Figure 1). If one thinks that CO_2 emission is a global problem, energy policies on this regard cannot be acceptable being regional.

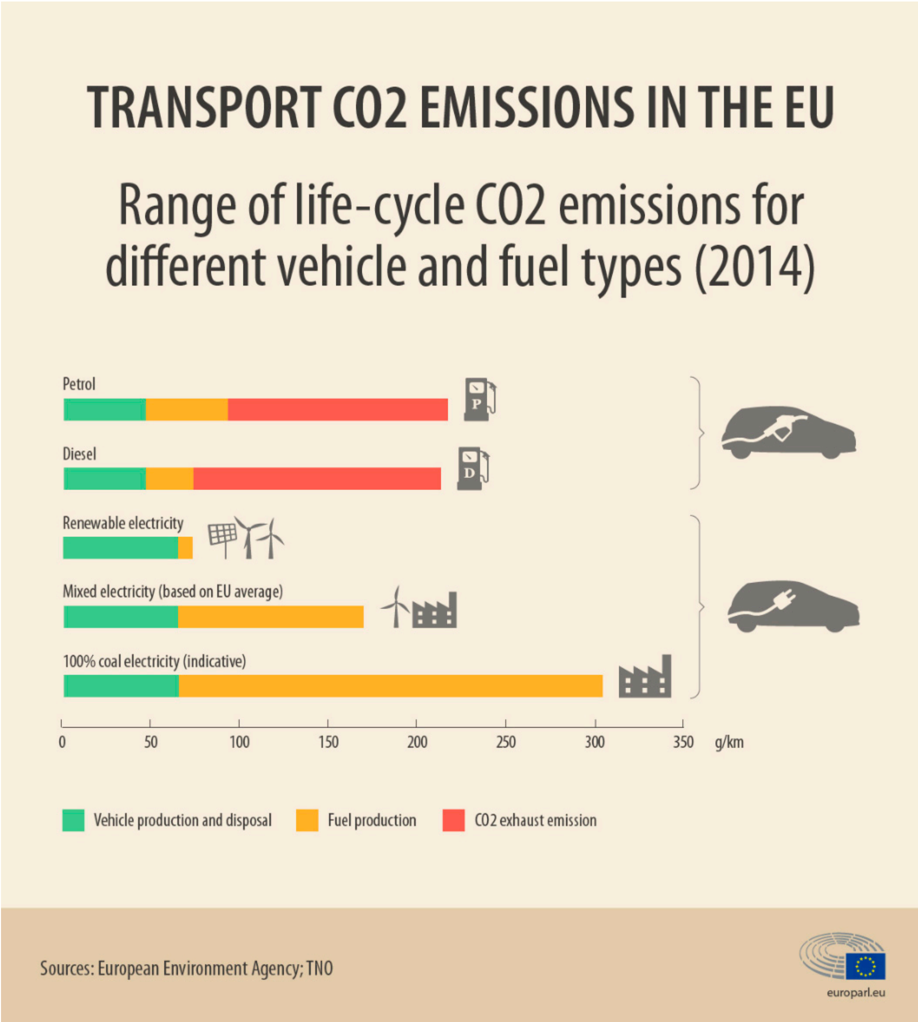

Figure 2. Life-cycle CO_2 emissions as a function of the energy source [13] with data from [14].

More recently, in April 2019, the international media echoed a recent study performed by the German IFO (Institute Center for Economic Studies, CESifo GmbH) conducted by Sinn et al. [15], who calculated that a Tesla Class 3 emits from 156 to 180 gCO_2/km during its lifetime with the German energy mix. This result in CO_2 emission ranges from 11% to 28% more than the modern Diesel E6d Temp engines. In addition, a life cycle analysis of the full electrification of road transport shows that the gaseous emissions would only be relocated from cities to the surroundings of large thermal power plants and manufacturing centers, as pointed out by Messagie [16]. Unfortunately, global warming cannot be relocated and atmospheric phenomena do not know the boundaries, as acid rain and clouds of particulate material (PM 2.5) have repeatedly demonstrated, as shown in Figure 3 [17]. In summary, for the combination of a massive electrification of road transport and the current global energy mix, the maximum benefit is a relocation of the emitted CO_2. As no substantial changes are anticipated in the current electric mix until 2030, the electrification of transport as a clear solution to the problem of climate change should be postponed [17].

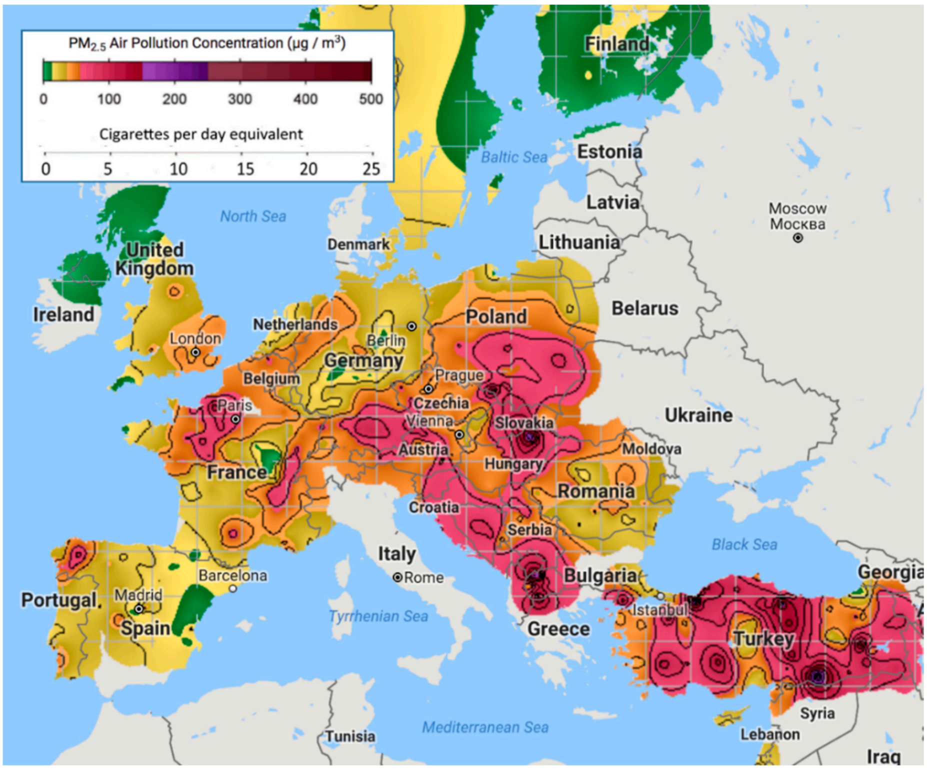

Figure 3. European PM2.5 levels. From [17].

The second problem with electric vehicles comes from the need of electricity storage. In a simple basic way, electricity must be generated as it is consumed. Of course, one can resort to batteries as the electricity storage solution although not in a significant amount for road transport applications. Like the ICE, batteries are an old well-known concept. In addition, batteries also involve harmful chemical compounds. Despite progressive improvements, batteries are a totally immature technology in the range of power and energy required for most road transport applications, where there is no competitor against successfully flexible liquid fuels [18]. There are four challenges that the development of batteries must deal with:

- The charging time of the battery is unacceptably long for many users [19].
- The energy density is unacceptably low with real autonomies below 250 km in compact vehicles [20] and around 300 km in sport urban vehicles (SUVs) [21].
- The lifetime of the batteries is limited and less than the vehicle life. Several studies [22,23] show this fact and discuss the risks and costs associated with their recycling or disposal in a proper way.
- The supply of raw materials for manufacturing such as nickel, lithium, cobalt, copper, and manganese among others is an emergent obstacle as they are reaching high prices quickly and gaining in importance on geopolitical strategies. According to Sarah Maryssael, global manager of metal supplies for Tesla [24], the main problem is currently the supply of cobalt, which is necessary for the anode of lithium-ion batteries; a Tesla Model X needs 7 kg per vehicle and a Tesla Model 3 about 4.5 kg [25]. This mineral is extracted mainly from the Democratic Republic of Congo, where human rights are violated through child labor and mines stand out by their poor safety conditions, among others [26]. Then, cobalt reaches the international markets and its origin is diluted due to the low traceability of the production chain. Finally, it is fundamentally processed in China, what exemplifies the potential of this technology for further economic stress and uncertainties. What would be the cost of these materials refined in western countries with EU security, environmental, and health standards? It would probably be exorbitant.

3. What Can the New Generation of ICE Provide?

Limitations to greenhouse gases (CO_2), gaseous pollutants, and noise emissions will be increasingly severe, forcing the automotive industry to invest in more innovative technologies for their reduction [10,27–30]. Real driving emissions tests are being adopted in the major global economic zones as this strategy expands the ICE operational range in which the pollutant emissions must be kept below the approval limits [31–33]. A revolution is approaching with respect to traditional gasoline and diesel engines making the boundaries between them disappear as deeper knowledge and greater control of the combustion process is acquired [34]. Advanced injection systems [35,36], turbochargers [37,38], organic Rankine cycles (ORC) [39], hybridization [40,41], multifuel solutions [42–44], or advanced combustion concepts are becoming a part of the ICE context. All these strategies are dedicated to extract every Joule of energy from the fuel. The research on aftertreatment systems based on monolithic reactors offers interesting possibilities to effectively clean the exhaust gases to incredible limits [45]. Nowadays, the automotive industry does not find anything too innovative or risky to meet the expected, medium-term demand for cleaner and more efficient ICE. Finally, fossil fuels are cheap and available. Oil depletion is no longer a topic of discussion as fracking technology has offered a new paradigm, leading the USA to the largest producer of fossil fuels in the world [12].

4. What Is Improving the Expectations in the New-Generation ICE?

ICE emits particulate matter, gaseous pollutants, and CO_2 locally. This is accepted as it is accepted that electric cars do not. Assuming both particulars are great arguments for the replacement of ICEs, what would happen if the situation were somehow the opposite? In a life cycle analysis, neither the production of the batteries nor the production of electricity is free of CO_2 emissions and pollutants [15]. The generation of electricity causes CO_2 emissions much greater than the synthesis of liquid fossil fuels, as shown in Figure 2, as it is an energy vector more difficult to obtain and transport. It can be similarly stated that the manufacturing of ICE generates CO_2 emissions, although less than in the case of batteries and electric motors [46,47], as also shown in Figure 2.

What can ICE do to increase air quality? We can affirm that modern Euro 6d Temp Diesel engines can clean the air from particulate and smog in heavily polluted areas, such as the situations referred in China [48]. The particulate filters of modern internal combustion engines reduce the level of PM10 below the mean atmospheric value, as shown in Figure 4 [49]. If one combines data in Figures 3 and 4, the advantages of ICE with particulate filters in countries such as Poland, where almost 50% of their energy mix depends exclusively on coal [12], are evident.

The technology is available, and the research is driven to allow the next generation of ICEs to act as air pollutant cleaners in large cities, whose source of pollution is not only road traffic of old ICEs. This is something that electric motors with batteries cannot do. The new Diesel Euro 6d Temp is emitting 80% less NOx than stipulated by the standard. This means that they are cleaning the air of emissions coming from other sources [50]. Effective energy policies are needed to renew transport fleets around the world, as justified in [51] for the Europe case, and promote in all countries the same emission standards for ICE as in the United States, Japan, or Europe. The discussion should not focus on the type of technology but on having in the streets the most modern versions of it.

Another important fact concerning ICEs is that the contribution of transport to global emissions of GWPs (Global Warming Potential) has historically remained at 11%. As shown in Figure 5 elaborated from the United Nations Food and Agriculture Organization (FAO) data [52], industry, agriculture, resource extraction, waste processing, and residential and commercial consumption do the rest. Therefore, a worldwide massive change to electric vehicles would mean a potential worldwide reduction of 11% of the equivalent tons of CO_2 that is emitted under the assumption of using fully CO_2-free energy sources for the BEVs batteries charge.

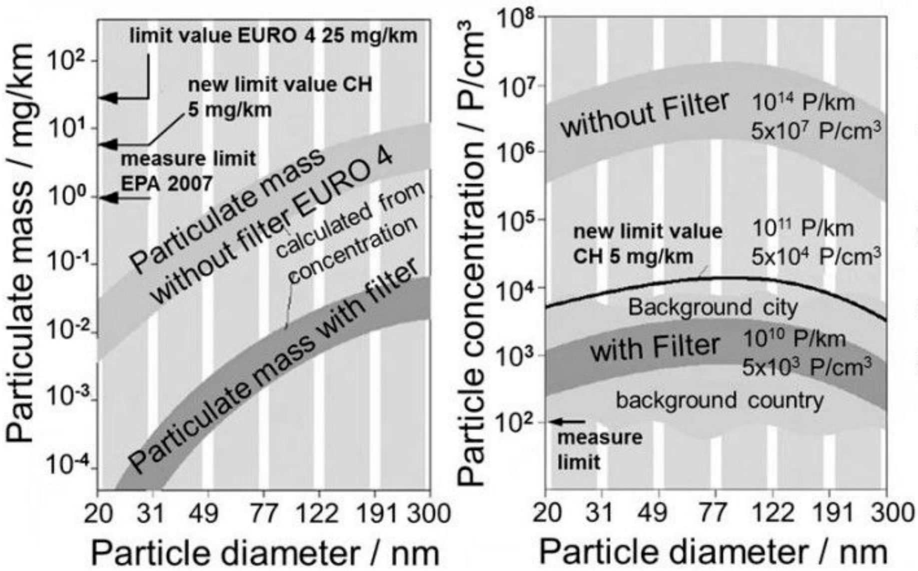

Figure 4. Diesel internal combustion engine (ICE) equipped with particulate filters as air cleaners in urban areas [49].

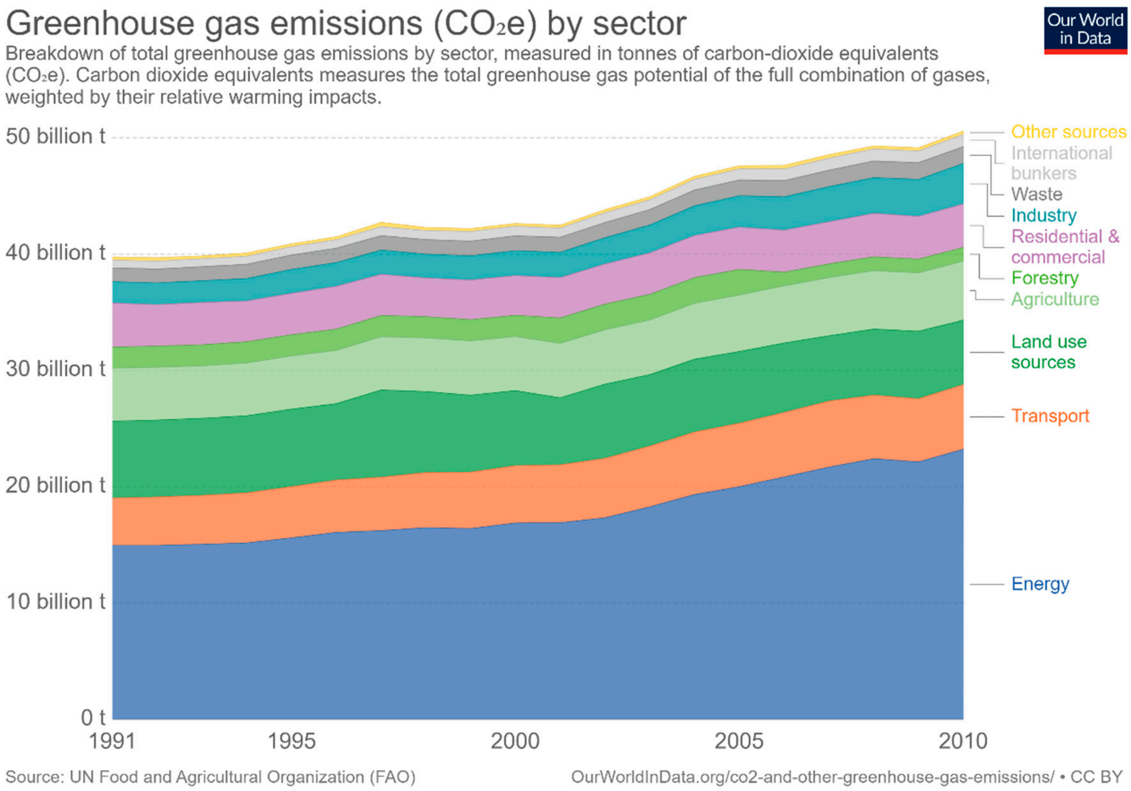

Figure 5. Breakdown of total greenhouse gas emissions by sector, measured in tons of carbon-dioxide equivalents [52].

However, only 10% of world energy consumption is free of CO_2 [12], which means that in best of cases, the reduction would be 10% of 11%. Even the previously calculated 1.1% is not fully reachable in a life cycle analysis, as shown in Figure 2. In the very long term, it can be argued that electric cars will substantially lower their CO_2 emissions if electricity comes exclusively from renewable or nuclear sources. As can be seen in Figure 6, despite the large dispersion of data in the sources [13,15,16,18], this scenario is far from being fulfilled today in most of the European Union countries. Considering countries like Germany or Spain with around 35% of renewable sources in the mix, the average equivalent CO_2 emissions are slightly better than 2019 Diesels E6d Temp. If we make an extrapolation to the future, in the central scenario, we would need to increase the mix of renewables by over 60% to have the same competitive advantage over combustion technologies based on compression ignition (CI) in CO_2 emissions [15,18]. Even if we reach 100% renewable, electric vehicles would never have zero CO_2-equivalent emissions if one considers the life cycle and not only local use.

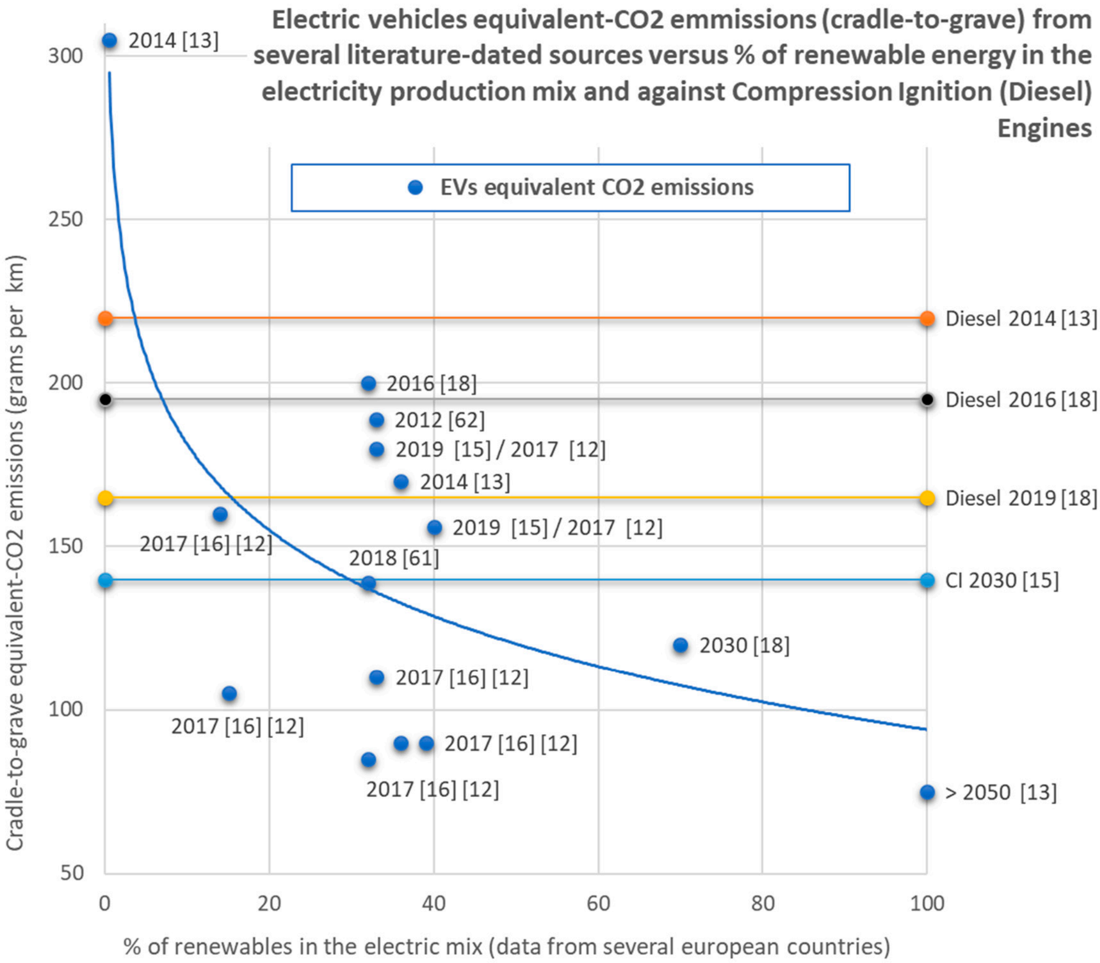

Figure 6. Equivalent life-cycle CO_2 emissions of electric vehicles as a function of the percentage of renewables in the electric energy production mix. Comparison with compression ignition (CI) or diesel engines. Elaborated from the references of this publication.

If one imagines that 60% of renewable sources in the energy mix were the medium-long term standard, could the ICE do so well? The answer is yes and even better if we use synthetic fuels from the capture and use of atmospheric CO_2 (CCU) [53]. There are already several R&D projects in Switzerland, Germany, and Canada focused on CCU. These are systems capable of transforming CO_2 taken directly from the air into liquid fuels called 'PtX fuels' (e-fuels, including e-Diesel). This is done by hydrogenation of CO_2 using H2 produced by electrolysis from renewable sources [54]. There are also projects to pump the captured CO_2 from the power plants to the oil wells and subsequently convert it into neutral oil from the CO_2 point of view. Other studies approach CO_2-capturing vehicles, both its own CO_2 emission and atmospheric CO_2, to generate CO_2 neutral fuel on board [55]. That way, the self-CCU could even contribute to a reduction in atmospheric CO_2. If the fuels used in these CO_2 capture cars were mostly biofuels [56], as is the case in Brazil, this would represent an efficient way to remove CO_2 from the atmosphere. However, the development of this technology is subject to the efficient recovery of exhaust gas energy from ICEs [57]. In conclusion, if a paradigm change is required, then vehicles acting as CO_2 captors to create a CO_2 circular economy may arise as the most efficient solution. They would eliminate the other 90% of CO_2 that transport is not producing [57]. This is an opportunity that BEVs cannot offer.

Public funding and government efforts should promote research to reduce polluting emissions, rather than to choose winners for an uncertain future. Direct subsidies to any industry or technology and the banning of others, without enough scientifically proved arguments, is the type of risk exercise that has never been successful. It seems that the European authorities have finally begun to listen to scientists and engineers, which are claiming for the cleaning potential of cities air contamination by the last-generation ICEs depollution systems [58,59], and that explain the facts of the situation [60–62]. The German Bundestag in May 2019 proposed that Euro 6d Temp diesel engines cannot be banned in German cities, not even the Euro 4 and Euro 5 when they emit less than 270 mgNOx/km (retrofit) that is pending being certified by the German Supreme Court [63]. In France, it is being studied to give the maximum environmental rating to Euro 6d Temp Diesel engines after finding that they are as much or cleaner than gasoline engines [64]. In general, promoting research activities of any technology, regardless of the field of research, has always provided great benefits for future generations, and has usually been the cheapest path for the society to progress.

Conflicts of Interest: The authors declare no conflict of interest.

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