

# Formula for Future

What is your reason for not changing?











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Formula for Future

Hold your horses! This is already fast.

Before going any further let me tell you something, “Your assumptions are your windows on the world. Scrub them off every once in a while, or the light won't come in.”

Do you agree? If yes, then stay with me until the end of this race, but to begin, do remember the following magical abbreviations:

EC: Electric Car

IC: Internal combustion car

HC: Hybrid car

FC: Fuel-cell car



# Chapter 0

Farshid: Hi everyone,

A warm welcome to everyone watching the world's most ever-waited car race, although it must be a bit hard for enthusiastic spectators watching it from home due to the sanitary situation (Covid). But we know that the excitement will override the disappointment.

My name is Farshid and today I have got this marvellous opportunity to comment on this historic car race taking place here in Le Mans, France. With my colleague Sri, one of the most qualified electric vehicle experts, and my super-duper friend!

Sri: Hey Farshid! No doubt that millions of eager eyes around the world are on this race. So before going any further let me begin with some technical information about the track and conditions and cars, to make sure that everyone knows what today's race is about.

So we have got 4 modern cars today trying to prove that they are capable of exceeding your expectations. In the end, the jury will decide which one is the winner based on different criteria such as speed, acceleration, horsepower, CO2 emission, comfort and price. I am sure many of you are watching this exciting contest just to decide what kind you are going to buy!

Farshid: I couldn't agree more Sri. Well, that's the purpose of this race.

The four cars on the track today are IC, EC, FC and HC. Each one is sponsored by very well-known car manufacturers. For example, Mercedes, Toyota, Tesla etc.

The track is 300 KMS and as shocking as it may sound, there are no restrictions of any kind - No speed limit, no fuel stations are provided and so on.

Ah, look over there; you can see them right now on the edge of 100km. That sounds crazy right! Cars are getting ready! Go ahead Sri, tell us more about these cars.

Sri: Which one should I begin with, I cannot choose. Ok, I will start with EC, based on my experience. (Laughter)



EC's are making big waves in the automobile world. These noise-free, emission-free, and high-performance vehicles are expected to make their IC counterparts out-dated by 2025. This race today will unveil the hidden technologies behind the EC, which recently became the world's fastest accelerating car. We will see how EC has achieved superior performance by analysing the technology behind the induction motor, inverter, lithium-ion battery, power source, regenerative braking, and above all the synchronized vehicle mechanism.

Farshid: Well, having identified all the advantages of EC, there are some drawbacks too. We will see about that.

Now, let me tell you about IC. Having driven an IC for more than 30 years, I just want to feel like I am driving something; by hearing that majestic sound of the engine.

I must confess to our viewers that IC does not need an introduction since it is as old as history.

Gasoline and air are mixed together, producing an explosive mixture and the basic job of the engine is to convert this explosive energy into motion. To contain the explosion the engine uses the cylinder, fitting snugly within the cylinder is a piston that slides up and down. Inside the cylinder, a spark ignites the compressed gasoline and air and the hot gases from the explosion push the piston downwards. The piston rod is connected to the crankshaft which converts the up and down motion into rotary motion. The crankshaft then drives the wheels through various pieces of machinery.

Sri: Oh! You do not have to overestimate the IC Farshid. Wait, the results of today's race will reveal everything. Another car, HC that is participating in the track is very affordable and easy to own. HC is a hybrid car. You might ask what HC is?

Let me explain. Basically, they use two power sources to move the vehicle. In Hybrid cars the fuel powers the engine and the engine powers the generator which generates power that is then used to power the motor which will drive the wheels or charge the battery. In times when it's needed, the battery can send its power to the motor to turn the wheels. Everything occurs in a straightforward way.

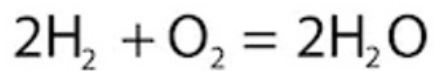
Farshid: And the last car today is an FC which has been stealing the spotlight recently. FC cars do not get as much attention as they deserve but they are here today on the track to prove everyone wrong. Hydrogen is a gas that contains a lot of chemical energy, if you ignite it, it will have an explosive reaction with the oxygen in the air and release energy. The only waste product is some innocent water.



Hydrogen

Oxygen

Water



Sri: That's right, there will be no CO<sub>2</sub> and no toxic gases, just a bit of water, and of course, uncontrolled explosions are great fun!

Hey Farshid, you can talk about it!

Farshid: No, I prefer to hear it from you, go-ahead.

Sri: Hydrogen cars produce the electricity themselves, this is ground-breaking..

Farshid: Yes, this is really a game-changer. FC has its own power plant on board. The fuel cell, which is pretty cool!

Actually, they use something called reverse electrolysis. This process is when hydrogen reacts with oxygen inside a fuel cell, so hydrogen comes from some built-in tanks, while the oxygen comes from ambient air all around us. And the only results of the reaction are energy, water, and heat which means they are emission-free. Isn't that great!

Sri: Yes, if you say so, that was such a comprehensive explanation of the different types of vehicles.



# Chapter 1

Farshid: Just under ten minutes until the lights go green in France before this clock watching car race. Drivers are getting strapped into their cars ahead of this afternoon's race. Are you excited Sri?

Sri: Yes absolutely, I'm bursting with excitement. Let me take advantage of this time to tell you how these cars came into the limelight and how these majestically powerful vehicles were given the spotlight.

Not an invention of modern times, the EC has a long and storied history. Let us travel back in time as we explore the history of the EC.

In 1834, electric cars were born. The invention of the first model electric vehicle is attributed to various people and the first credit is given to an American, Thomas Davenport. The heyday of electric vehicles is considered to be until around 1900 when the vehicular land speed record was held by these new-born vehicles.

However, by the 1920s the EC stopped being commercially viable for the following reasons: gas power being more accessible, the high cost, limited performance and the short-range of the battery led to a worldwide decrease in their use as private motor vehicles.

By the late 1960s there was a change, gas prices began to climb sharply, and also the concern over air pollution caused by hydrocarbon-fuelled vehicles made governments pass laws promoting the production of EC's. Around the same time, the first manned vehicle drove on the moon. NASA's Lunar rover ran on electricity, helping to raise the profile of electric vehicles.

To your astonishment no doubt, the real revolution in the field of electric vehicles came out of Japan. Toyota introduced the first commercially mass-produced hybrid car, the Prius. It was a hit from the start with close to 18,000 units sold in the first year.



Farshid: Wait a minute, you almost talked about a century with no Tesla in it!

Sri: I will tell you now.

In 2006, Tesla unveiled the Tesla roadster which was a breath-taking invention. What Tesla did was a giant step towards more efficient batteries that have been a sore in the eye of the IC industry. This year, General Motors released the Chevy Volt which marked the first plug-in hybrids.

Farshid: General Motors, the same company which developed the fuel cell cars introduced the Chevrolet Electro van with a range of 193 KMs and a top speed of 112 km/h.

Sri: Ok, all that said, where do we stand now and what does the future look like for these cars?

Farshid: That's the million-dollar question, as right now there are more choices than ever before. Besides the models for IC, there are 23 plug-in electric and 36 hybrid models available on the market. No doubt, for a sustainable future, ECs will play a vital role and are a promising friend to our transportation desires.

Sri: Oh my god! This race show is more informative than I thought! Fantastic!

Farshid:

Instructions are given by officials, the cars are in their positions, referees get set, and your eyes are not deceiving you.

Not long left, only 20 seconds, the talking has stopped... the championship will now be decided on the track and the dream begins at 5...4...3...2...1...GOOOOO!!!!



# CHAPTER 2

Farshid (Excited): Oh my goodness, I am excited as a child!  
Look at that, the cars are out of the race and the Safety Car has been deployed.  
EC leads IC, HC, and FC.

Sri (Excited): It is a pretty decent start from EC and IC. Now, HC loses some places over there.  
Terrific job from FC, although expectations were lower than what we see now.  
A great move from IC helps to overtake EC on the outside of the first turn.  
Now the four cars are going at their maximum speed on the track, with IC leading the race.  
IC extends his lead over EC to 3.5s.  
HC is ahead of FC which is now 18s behind IC.  
No doubt you are more eager than me to know about the speed and acceleration of those cars.

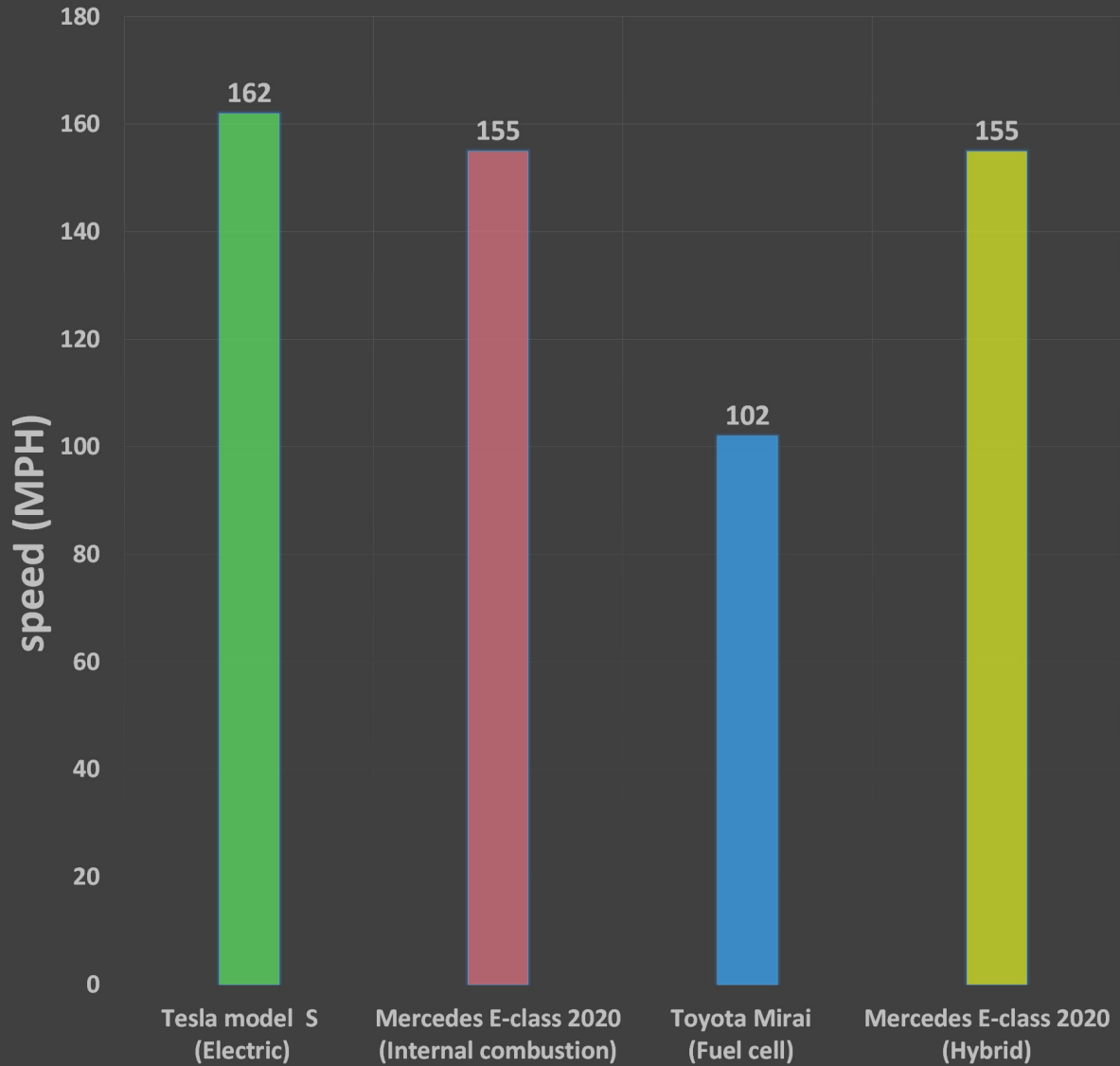
Farshid: Yes, cannot wait to see how fast they are in more detail.

Sri: OK, here is the information, if you want to purchase one or change the one you already have for a better car. What I am going to explain are the latest models of these car types produced by the best car manufacturers around the globe.

EC: Immediate, quick, smooth, and its silent acceleration is the EC's trademark. Some of the latest models have a top speed of 90 km/h and if you spend more and want to go faster there are some with a 261 km/h top speed.

Most models/versions available can do 100 km/h, almost half of the table is occupied by Tesla with its three electric cars, available in several versions. After the most recent upgrade of the Model S and Model X, this company took the top eight spots, offering a 0-100 km/h as low as 2.4 seconds.

**Top Speed of 4 Popular Sedans**



IC: To your astonishment no doubt, while I am talking here, there may be a car out right now that goes faster than the latest record. However, some fancy models, being as fast as 500KM/H, you can of course find any option from slow ones to some hitting 300KM/H and a wide variety of acceleration with some being as quick as 2 seconds from 0 to 100 km/h. Actually, IC's have the most varied models and have existed for ages.

HC: While many electric vehicles have significantly lower top speeds and some are even a little bit unstable on the highway, hybrid cars get enough power from the gasoline engine to go as fast as 161 km/h. The real matter for hybrids is acceleration. Since the smaller electric motors that most automakers use don't produce much horsepower, a relatively fast hybrid car can go from zero to 97 km/h in about 6 seconds. And a typical hybrid car accelerates from 0 to 100 in around 10 seconds. For some people, that may be too slow.

FC: A new record was just set for the hydrogen fuel cell-powered land speed. The record at the Soggy Dry Lake Bed in California was broken by a speed of 151 km/h. It may not sound fast, but it's the fastest speed reached by a FC. Hydrogen, as a fuel, is seen as a remedy for helping to create a clean future for vehicle power.

Farshid: Wow that was quite invaluable information for those of us who care about speed and acceleration. Thank you Sri, let's get back to the race and see what is happening over there. Yes, as I guessed the IC is as quick as a lightning, followed by EC, HC, and FC.

Farshid (unimpressed): The other cars are knocking HC sideways!

Sri (Excited): IC is showing his grit Farshid.

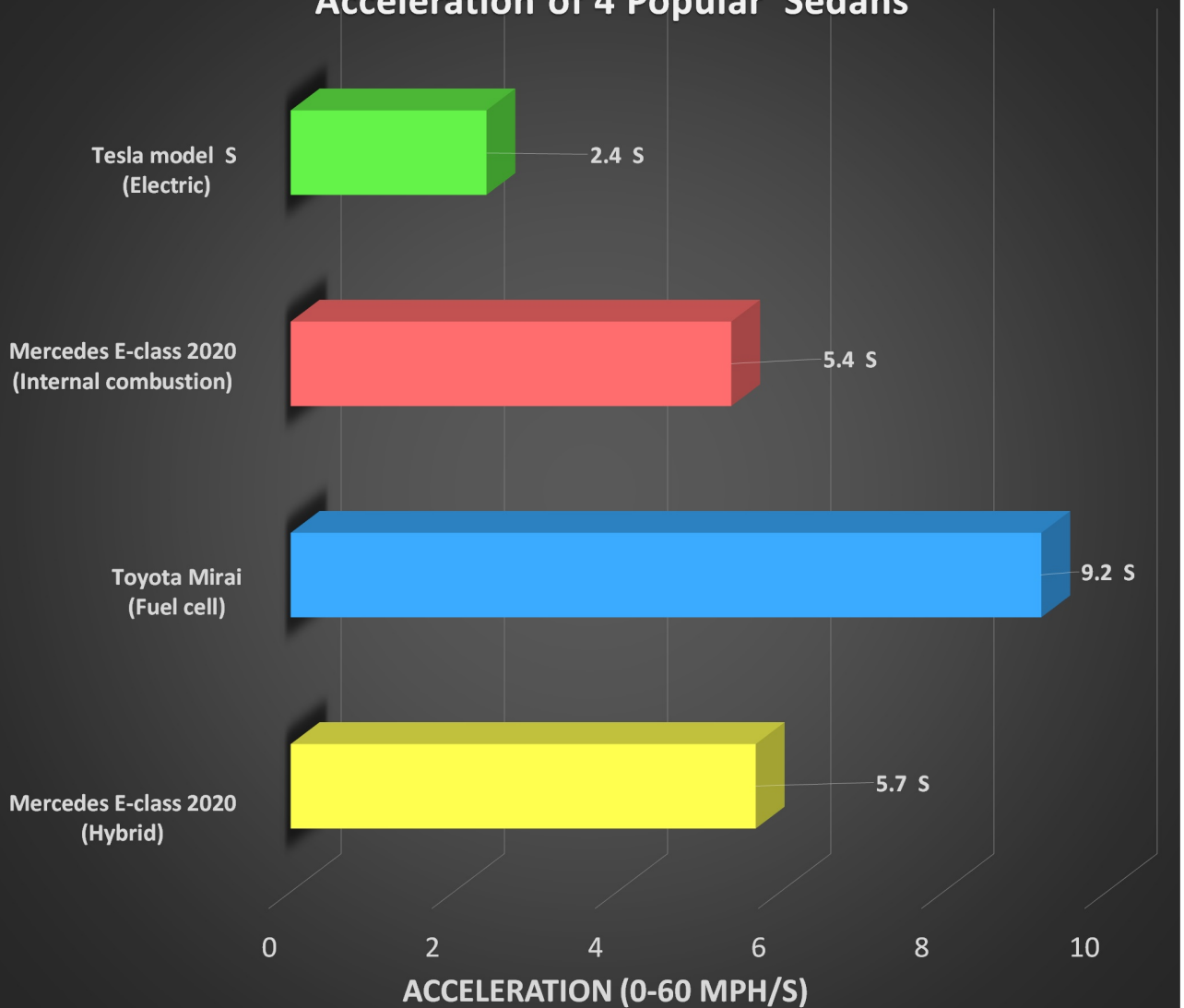
Farshid (concerned): Good driving IC, but when will the win come?

Farshid (conversational): Well, better to wait until the end of the race to judge, since here winning is not only about being first, but also about fulfilling certain criteria.

Sri: What about the pollution, it was one of the factors that IC supporters were really worried about?

Farshid: That is right, let me explain more in a few minutes all you need to know about how green these cars are.

## Acceleration of 4 Popular Sedans



EC: The researchers say average “lifetime“ emissions from EC’s are up to 70% lower than petrol cars in countries like Sweden and France (where most electricity comes from renewables and nuclear power sources), and around 30% lower in the UK.

They said that the picture for EC’s will become steadily more favourable as nations shift to clean electricity.

IC: Cars, trucks and buses powered by fossil fuels are major contributors to air pollution. In fact, transportation emits more than half of nitrogen oxides into the air. While this air pollution carries significant risks for human health and the environment, by using EC and FC we can significantly reduce emissions from our cars and trucks and help transform transportation.

According to a study, every second car on the streets of the world could be electric by 2050.

This would reduce global CO2 emissions by up to 1.5 gigatons per year, which is equivalent to the total current CO2 emissions of Russia.

HC: Depending on the model, hybrid vehicles can reduce smog pollution by 90 per cent or more in comparison to the cleanest conventional vehicles today. Plus, hybrids will cut the emission of global-warming pollutants by one third with the future hybrid models aiming to reduce global warming pollutants by even more. Also, with renewable technology advancements, such as wind and solar, the source of the electricity for the hybrid electric motor component can be renewable and environmentally friendly.

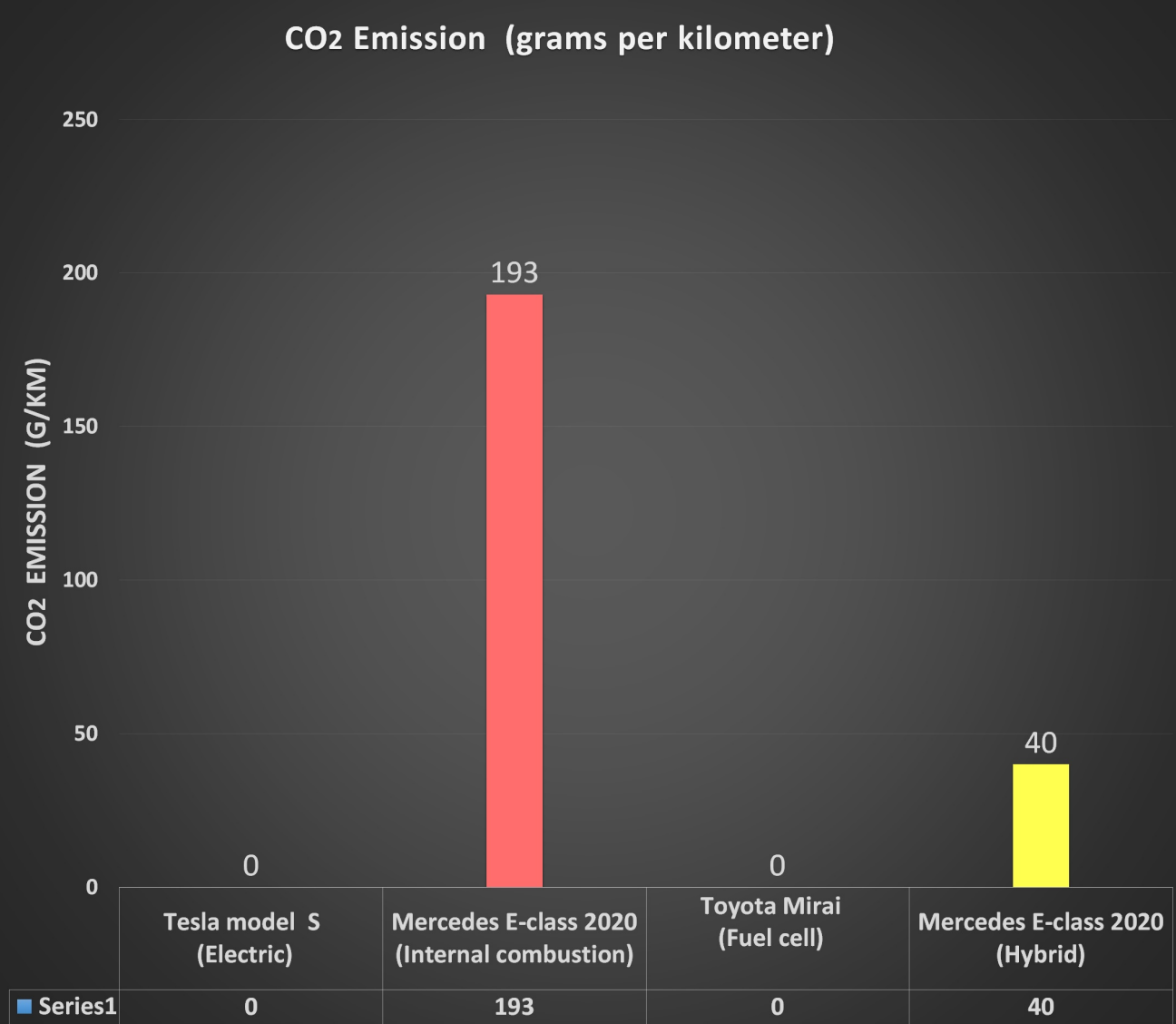
FC: Hydrogen-powered fuel cell electric vehicles emit none of these harmful substances — only water (H2O) and warm air. Sounds amazing, right?

I think it is fair enough to see which one of these cars is good for you Sri, for me and all the people around the world.

Sri (conversational): Well, as obvious as it is, let’s leave the judgement for the referees.

Can you see that dark smog behind the IC?

Farshid (conversational): Yes! Yes! IC seems to have annoyed the other cars with the smog released behind and is polluting the air we breathe.



# Chapter 3

Sri: On the track, HC is very quick, getting away well and here comes FC lapped on the inside. No! He cannot quite make it through!

No change at the front as IC still leads the way by 3.2 S, and EC is 5.7s off HC and FC falls behind them all. Fantastic stability!

Farshid: Oh, oh I see a collision to the back of IC by EC - even I can see the scratch too. Unbelievable how EC did that. Maybe he lost control. This is going to separate things out, if you want to win, you have got to get passed all the other ones.

Sri: That seems like it will cost quite a bit of money to repair the car. I mean after the race these cars will be completely repaired and well maintained.

Farshid: Speaking about expenses! How much do those four cars cost on a normal basis and what is the average running cost?

Sri: Well, that acts as the prime factor for many first-time buyers. It is obviously a topic that cannot be summarized in a few words; however my main focus will be on EC, HC and FC's price and running costs, rather than IC, since IC's are very well known and almost everyone is using them and knows the information.

A good mini model of EC and the cheapest in that range start from \$30,000. It goes up to around \$135,000 for a very good one. Although the initial price of an EC can be higher than that of an IC in a similar class, it can cost half as much per mile to run. An electric motor will never need to be taken in for an oil change, nor a filter, spark plug or timing belt replacement. Thanks to regenerative braking, there's much less of a load on the brake pads and brake discs. In addition, the energy costs are much more affordable.

In France, a full charge that can provide a range of around 400 kilometers costs around 9 euros during peak hours, but can drop to just 6 euros during off-peak hours. In countries where electricity is more expensive, the cost of a full charge is no more than 16.50 euros.



In addition, free charging is offered at some shopping mall charging stations and at certain workplaces. ECs are also eligible for tax breaks, making them more competitive in relation to combustion engine cars. In France, the eco-bonus is 6,000 euros.

Although the prices of EC batteries are currently high, they are on a downward trend and shouldn't detract from the affordable overall cost of owning the vehicle. Since the maintenance and energy costs are lower, it works out that electric cars cost far less per kilometer and give drivers plenty of perks in big cities (access to priority lanes, no urban tolls, specially marked parking spaces and more).

Farshid: Good to know before buying one. And the price for EC is going down. I would like to ask for a favor from our technical team, can I have my screen shared? Yes? Oh, that is great, thank you. As you can see on my screen, this is mainly the inner parts of these cars and as I go further, I will be explaining some important points about the fuel system and the main parts of each type.

Sri: - Go ahead, one eye on the match, and the other on your screen.

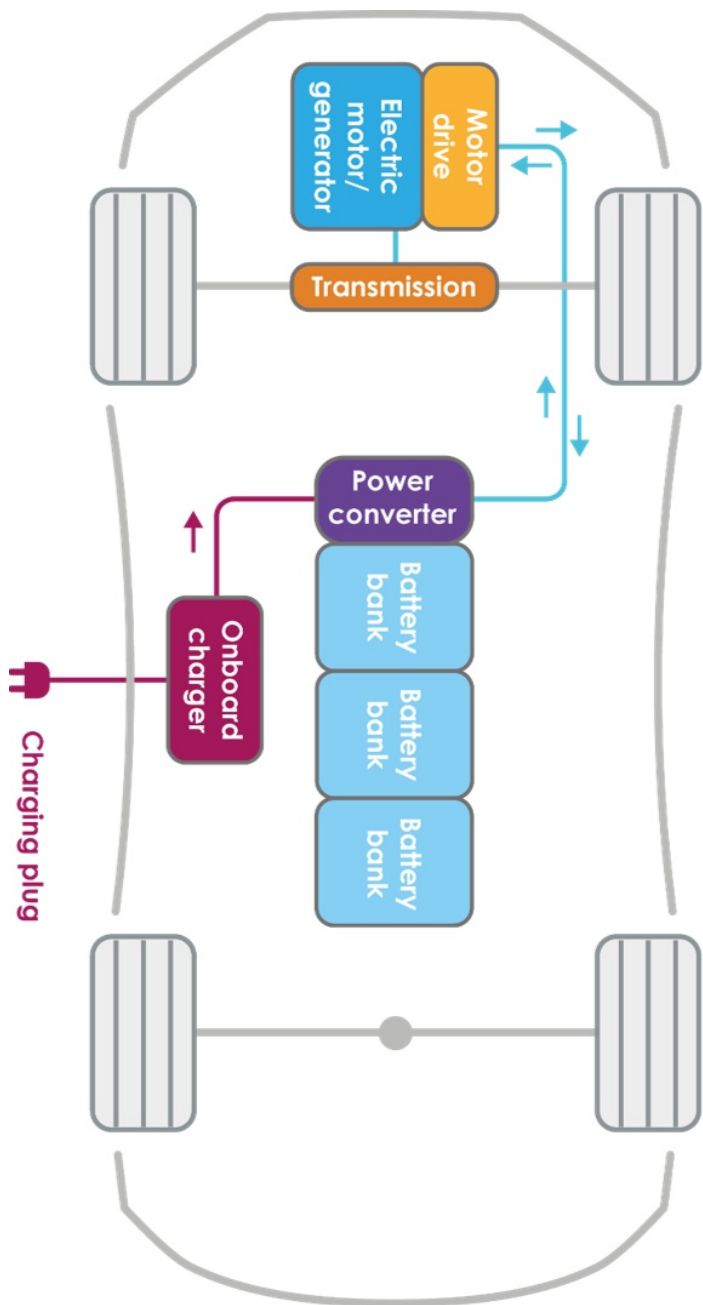
Farshid: Ok, first and foremost, I will be talking about EC, as I am 100 percent sure that everyone is interested to see what is inside of it and how it works.

In fact, the science behind the electric car is surprisingly simple. Its basic principle is the alternating current (AC), for which we have Nikola Tesla to thank more.

Well, most ECs convert the DC from the batteries into AC. Since electric cars do not have an internal combustion engine, they use their space quite differently. You would normally expect a big, bulky battery to be in the front under the hood, but it's completely different in an EC. They have around 7000 lithium-ion batteries that sit under the flooring. This battery pack has a longer lifespan, making them ideal for the car.

One of their vulnerabilities is overheating and thermal breakdown, that is why electric cars have coolant running between them to prevent overheating.

At the back of the car you will find the inverter which is what converts that DC into AC and gives power to the engine, but it cannot do that without the induction motor which is also at the back. And it takes the AC current that just came from the inverter and creates a rotating magnetic field that causes the motor to turn.



Now, electric cars do not have a gearbox or gear lever and all of them are automatic, with a single speed transmission that transmits power from the induction motor to the wheels. This is how the electric motors transform electrical energy into mechanical energy.

Further, where it gets more interesting, when you accelerate while driving, the car uses more energy. But, when you brake, the energy is transformed into electricity through the induction motor. Then, that electricity travels all the way back to the battery pack and is stored so you can use it later. Now, that is efficient.

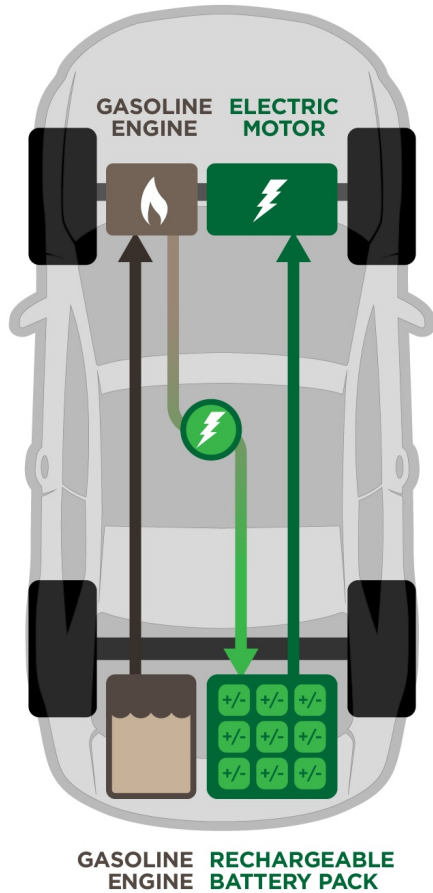
HC: Hybrid cars use both fuel and electricity with both internal combustion and electric motors driving the wheels and batteries that store energy. The essential idea of a hybrid vehicle is that those two types of propulsion systems work in harmony. A gasoline or diesel or biofuel internal combustion engine, it has two jobs, first, to provide motive power and to help charge the batteries of the vehicle. Second, electric motors that are located in different places in the vehicle depending on the manufacturer. Both motors are connected to a transmission and then to the driven wheels - the drive shaft.

The third component is the battery or a series of batteries which store or send their electricity. Batteries in hybrid vehicles do not ever need to be plugged in, because their charging needs are met by the management system of the vehicle, so they never are a burden on your home electricity bill. Now, the way hybrid manages all of this technology is through a kind of mission control specialist which is in fact a computer or a series of computers. They make decisions about where power is coming from and where it is going. So while you are using the steering, brake and accelerator and may be listening to music, there is a lot going on. For example, if you are driving along at 20 KM/H, the car may ask the battery if there is enough power on hand for the electric motor to be your motive power.

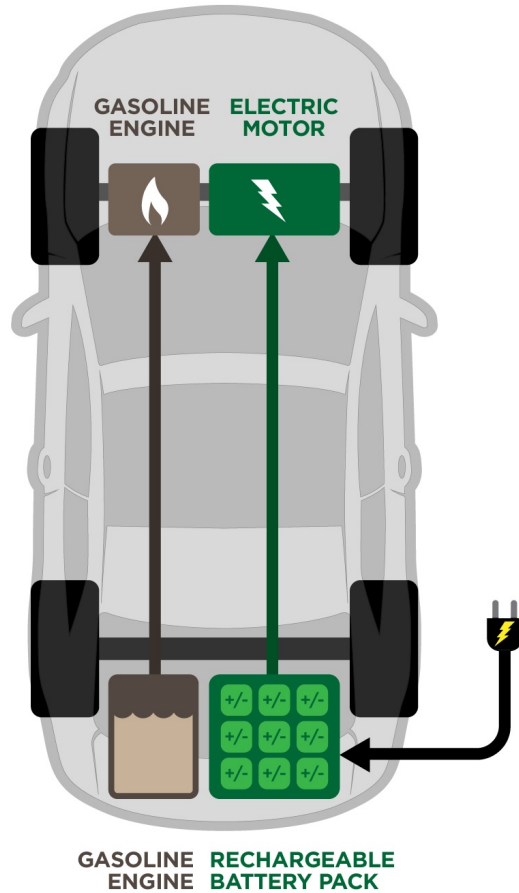
If the answer is yes, the internal combustion engine turns off. If the battery resources get too low, the engine comes back on to power the vehicle and to recharge the battery. And whenever you brake the power goes back to the battery which is called regenerative braking as we explained in EC too.

HCs are enjoying the best of both worlds, on demand power, significant fuel saving and lowered emissions and smooth, quiet emission-free electric motive power as well.

Hybrid  
(non plug-in)



Plug-in Hybrid  
(plug-in)



Sri: Let me give you the latest update of the race as EC is just ahead of 0.5s to IC and the other two are still in the same position. I am astounded by EC and how this car has improved in leaps and bounds just in a couple of years. You can keep telling us more Farshid.

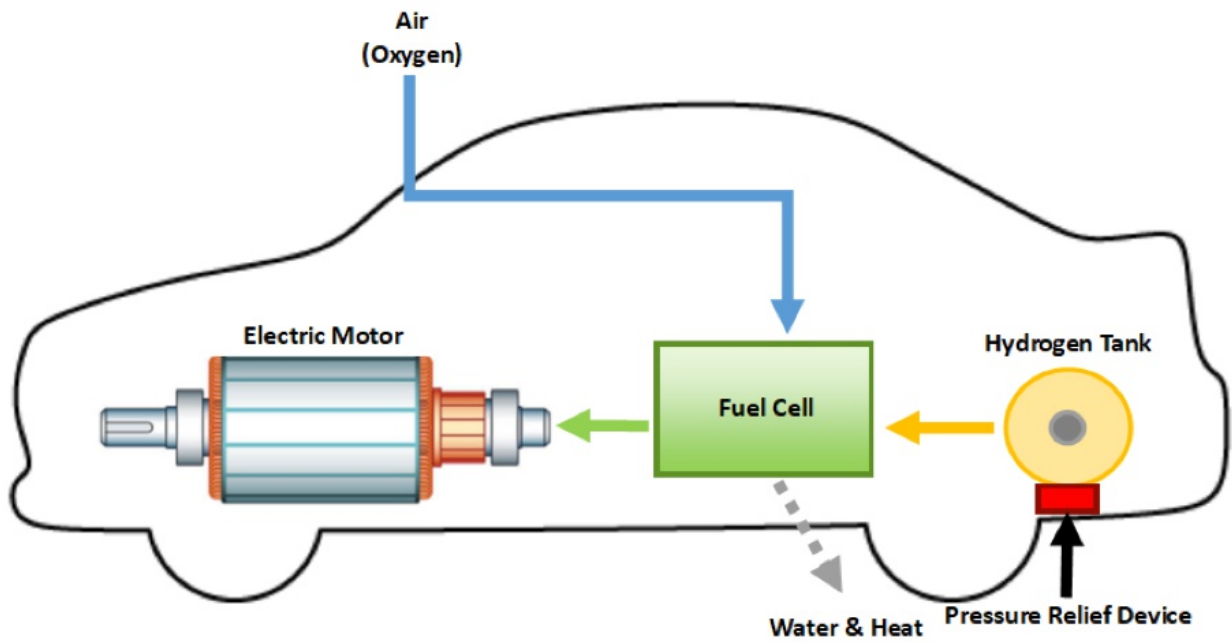
Farshid: OK as I was saying! FC has the power to change our world. Clean, quiet and pollution free, these are not just random words, but the reality that we have expected for ages.

They look like any other car but work very differently, when you turn the key hydrogen and compressed air flow to the fuel cell module which contains the fuel cell stack. A fuel cell engine consists of the PEM (proton exchange membrane) coupled with the systems required in a typical automotive engine. The electricity produced by the fuel cell is delivered to the electric drive system in the vehicle. The drive system converts the electrical power into the mechanical energy that drives the wheels of the car. The dual cell is 2 to 3 times more efficient than your gasoline engine and does not create pollution. Additional benefits include increased performance and on-board power, higher reliability and greater flexibility in vehicle design and engine layout.

A single PEM fuel cell is made up of two plates, two electrodes and two thin layers of platinum based catalyst, separated by a plastic membrane which when fed with the fuel reacts electrochemically to create electricity. Hydrogen from an on-board storage tank and oxygen from air are fed through channels in the plates.

Hydrogen flows on one side of the membrane and air on the other. The catalyst splits the hydrogen molecule into protons and electrons. The protons can pass the membrane; the electrons cannot and have to pass through an external circuit creating useful electricity.

On the oxygen side of the membrane, the protons and the electrons react with oxygen from the air in the presence of the second catalysis layer, generating water and heat. By stacking together single cell slices in a loaf of bread, you make a fuel cell stack to produce the required amount of power.



# Chapter 4

Sri: Wow, I am amazed by all these useful tips and information. I am sure that we all know what car can not only be a good purchase for individuals, but also a good friend to the environment and our societies.

Let us get back to the match. Unbelievably EC has overtaken IC and now leads the race and if this continues for a few more seconds, EC is winning on at least two of the criterion (Speed and acceleration). Oh, look, this is happening, this is reality, this is a long dream for many of us coming true.

**YES! YES! EC WINS, IT WINS THE RACE.** Oh my god. I am over the moon, this day I will never forget. **NEVER!**

Farshid: Oh, I am so happy for you my Electric caroholic friend. Congratulations to everyone who has been watching and supporting ECs. But before drawing conclusions, let us see what the jury decides, EC has a high chance though.

I would like to introduce our jury members, Sobhan (HC and FC senior specialist), Hassan (IC race engineer) and George (EC production manager).

Now, the jury is deciding the winner and you can see the table. Points from 1 to 5 are being given to cars, with 5 as the highest and 1 the lowest. On the scoreboard you can see that 4 cars are judged based on different factors, namely, pricing and maintenance costs, speed, acceleration, emissions, stability and so on.

As you see on the table and as it is crystal clear that EC is dominating here and wins the match with very good points from our referees.

Sri: It is time to celebrate, but do not forget to wash your hands and wear your masks. And take care of your family and loved ones. I hope to see you at another race. Goodbye.



**FUELED BY  
RENEWABLE ENERGY  
SOURCES**



**WINNER OF THE  
FORMULA  
4  
FUTURE  
“EC”**



**HIGH SPEED  
&  
FASTER ACCELERATION**



**HASSLE - FREE  
MAINTENANCE**



**ZERO EMISSIONS**



**LOWER RUNNING COST**



**SAFEST CAR**









“If you have a great solar roof, and you have a battery pack in your house, and you have an electric car, that scales worldwide. You can solve the whole energy equation with that.” Elon Musk

