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[Driving Range for the Model S Family](#)

By JB Straubel, Chief Technical Officer

As the Model S family has expanded over time it has become more relevant to compare range from one variant to another with a consistent set of assumptions so our customers can know what to expect and make the best decision to fit their needs. This can be a bit difficult since the background test methodology and standards from the US EPA are evolving over time. There are also many customer vehicle configuration choices, both before and after purchase, that can affect range as much as or more than the vehicle platform choice itself. The most important example of this secondary configuration is the wheel and tire selection. This short paper will hopefully help to compare amongst all of the Model S family and understand how tire choices impact range as well.

EPA 5-cycle Range

There are many different ways to compare vehicle range but the standard in the United States is from the EPA on a complicated combination of different driving conditions, all blended together. This is the number that you will see on the window sticker of a new car. We have written about this test method in several [previous blogs](#) that are still very relevant.

A comparison of all Model S variants based on EPA 5-cycle range is as follows:

Variant	EPA 5-cycle Range₂ [miles]
85D	270 ₁
P85+, P85, 85	265
P85D	253 ₁

60	208
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1 Values for 85D and P85D are pending final confirmation from the EPA and use new dual motor torque sleep control software available by the end of January 2015.

2 In the table above all vehicles, including the P85+, are using 19" tires. See the paragraph below about performance tires below to understand their impact on range.

Cruising Range

Another range comparison that we have found useful is constant speed cruising range from one vehicle variant to another. If you are travelling on a road trip with mostly highway miles this is a useful value.

Variant	65 mph Range¹ [miles]	75 mph Range¹ [miles]
85D ₂	295	249
P85+, P85, 85	285	242
P85D ₂	285	240
60	215	183

1 All vehicles in the table above are using 19" tires.

2 Using new torque sleep control software available end of January 2015.

The physics of aerodynamics affects all moving vehicles (gasoline or electric) the same: reducing efficiency and range at higher speeds. This effect is more pronounced at higher speeds since the drag force of the wind on the vehicle increases with the square of the velocity, from 35 to 70 mph it doesn't just double but goes up by four times!

Despite this aerodynamic challenge, highway cruising is where the unique benefit of the dual motor cars, to torque sleep one of the drive units when not in use, is most apparent. Much like a modern computer that can actually sleep in between keystrokes, the dual motor Model S will quickly torque sleep a drive unit when torque is not needed and instantly wake it up as the accelerator is pressed to command more torque. It continues spinning while asleep and the digital torque wake up is so fast that the driver can't perceive it. It is far superior to the slow and awkward engine startup on stop-start hybrid vehicles.

The software update to implement torque sleep will be downloaded to the dual motor fleet by the end of January 2015 and will substantially improve the range of dual motor vehicles by roughly 10%. All tables and graphs in this paper are shown including the benefits of torque sleep.

Performance Tires and Wheels

With tires and wheels there are some physics tradeoffs between handling, traction and efficiency (rolling resistance and aerodynamic drag.) At the most intuitive level, as a tire becomes more sticky it will corner and accelerate better but also have modestly higher rolling resistance. Customers can make decisions on tires and wheels independently across all variants of the Model S. Of course these decisions are also often changed throughout the life of the car (summer vs. winter tires for example.)

The 19" Cyclone wheel and tire that we offer on most of our vehicles is the best configuration for range, efficiency and cost effectiveness. The 21" wheel/tire upgrade yields substantially improved handling performance and vehicle dynamics. The 21" performance tires are a more commonly selected option on our performance variants (P85, P85D and formerly P85+) since many of these performance-oriented customers want the best possible handling. There is however roughly a 3% reduction in EPA 5-cycle range (compared to the values presented in the table above) for the selection of 21" performance tires to any of the Model S variants. For customers who care about handling and performance driving this is a tradeoff that we think is well worth it. For customers who are focused on range, efficiency and best value the 19" wheels can be configured onto any Model S variant to achieve the values in the EPA table above.

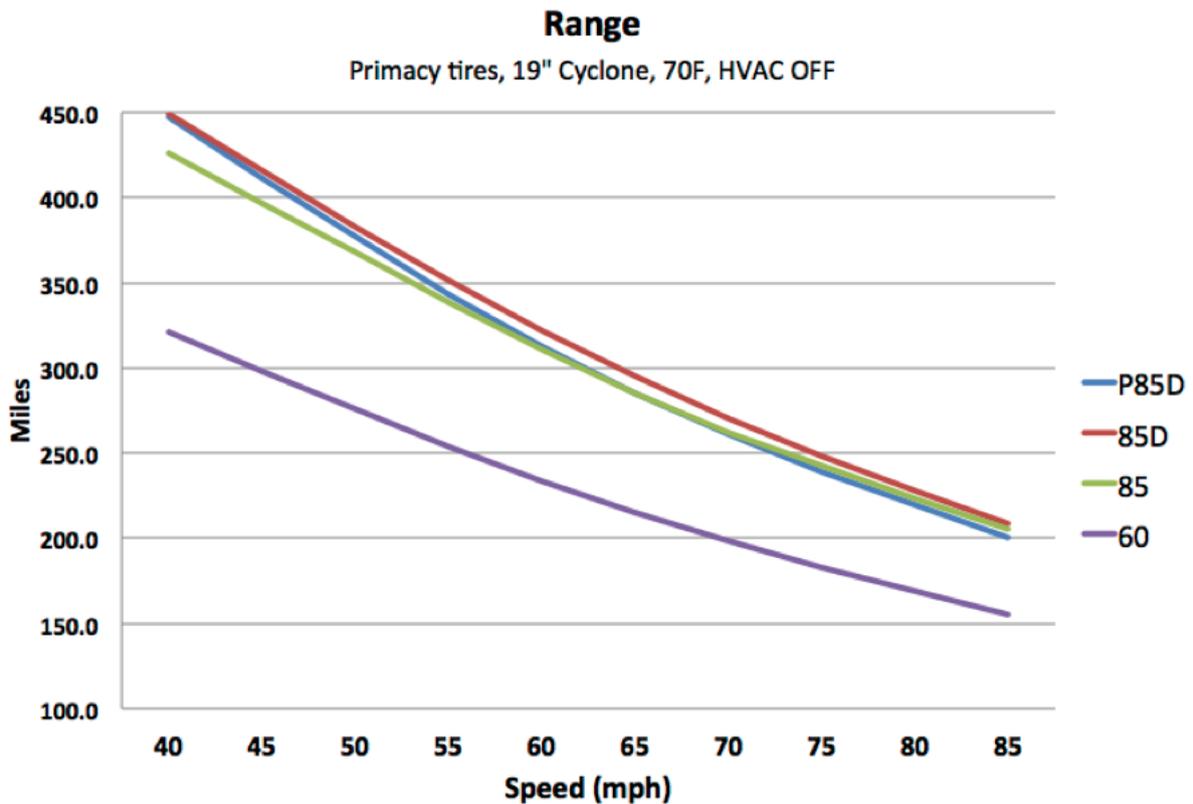
As an example calculation, if a standard Model S 85 with 19" tires having 265 miles of range is changed to 21" tires the range would be reduced by ~3% to about 257 miles. This is the range that most customers of the former P85+ configuration experience since nearly all of those variants are configured with 21" tires.

It is also worth noting that all new tires have a break in period for the first ~1,000 miles where the total vehicle efficiency is reduced by up to 5%. This can surprise (negatively) new owners or customers who have just changed their tires but will quickly improve back to a normal baseline.

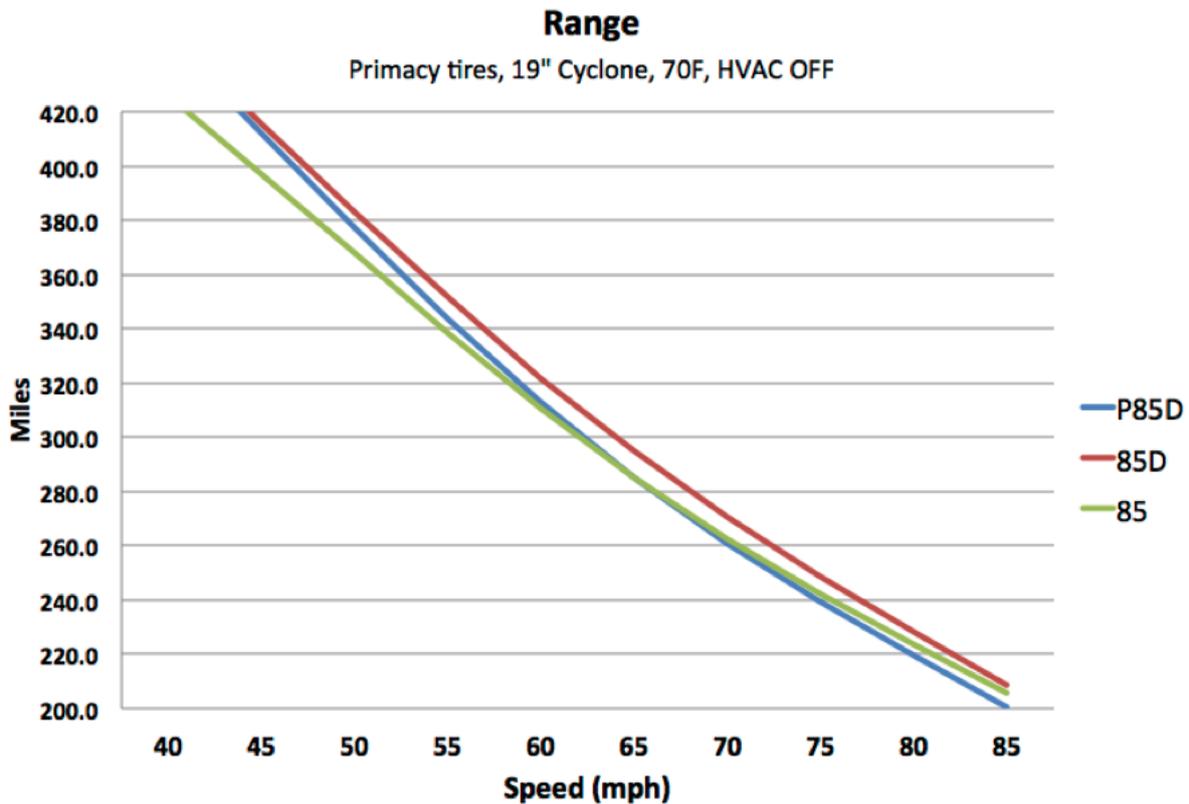
Range vs. Speed

There is naturally a strong sensitivity to range based on vehicle speed as mentioned above and we have discussed in some detail in the previous [Model S range and efficiency blog](#).

The best way to see a more complete picture of this is actually in a graph of what range is possible versus driving speed.



And if we look in even more detail at the differences just between the 85kWh battery pack variants you can see the interesting complexity in how the dual motor operates. At some speeds the P85D is more efficient than the base 85 and equivalent to the 85D. At other, higher speeds the 85D and 85 are slightly more efficient, with higher range, than the P85D.



Summary

Which battery, drivetrain and tire configuration is best for you will depend on what kind of driving you enjoy most. At Tesla we pride ourselves on transparency and providing customers clear data to understand our products. With the information above hopefully the choices and performance expectations are clear.

We have also added all of this information, and even more such as cabin heating and air conditioning loads (HVAC), day/night driving, windows up/down, 19" or 21" tires and outside temperature into a [powerful range tool](#) that you can use to simulate any driving conditions and any vehicle choices. Feel free to play with this and give us feedback if we can improve it!

Answers to Common Questions

Q: Which drive unit is able to sleep, front or rear?

With the P85D we put the large, rear, drive unit to sleep while cruising. We choose to sleep the rear unit since the new generation small front drive unit is actually more efficient at converting battery DC electricity into mechanical shaft power. So we benefit from using the small, front drive unit more of the time when it can provide all of the torque requested. In the 85D both drive units are the same and we can sleep either unit, front or rear to best optimize efficiency.

Q: Are standard or cyclone 19" wheels more efficient?

Cyclone 19" wheels are slightly more efficient than the standard, base, 19" wheels. This efficiency gain comes from an aerodynamic improvement of the wheel itself and the 19" tire effects are separate. The aerodynamic benefits are most pronounced at higher speeds so you will see the biggest gains at 65mph or 75mph cruising. For instance, the 19" Cyclone wheel gives roughly 2% more range than the 19" standard wheel at 65mph. The difference will be less than 1% in city driving however.

Q: What are the best 19" tires?

The Michelin Primacy 19" tires give roughly 3% more range than the Goodyear 19" tires at 65 mph. The difference is greater, up to perhaps 5% difference in range, in slower city driving. We do not have any suitable production tires better than the Michelin Primacy to offer yet but are constantly evaluating and testing new options. Many tires claim larger improvements than we actually see in real world testing so beware of aftermarket label specifications. Tires are an area of increasing focus for us as a company.

Q: Do wheel mass differences contribute to range differences?

The mass differences between the various wheel and tire options are quite small. The variance in range is created from rolling and aerodynamic differences between them. (see answers above)

Q: Will we offer a dedicated Aero Wheel design again?

The customer take rate on our previous Aero Wheel design was so low that we could not justify continuing the production and supply chain complexity of it. In general we are working to simplify the complexity of options available and eliminate those where we see fewer than 1/20 people choosing an option. In addition, the newer Cyclone wheel captures much of the aerodynamic benefit of that the dedicated Aero Wheel design did over the standard, base 19" wheel.