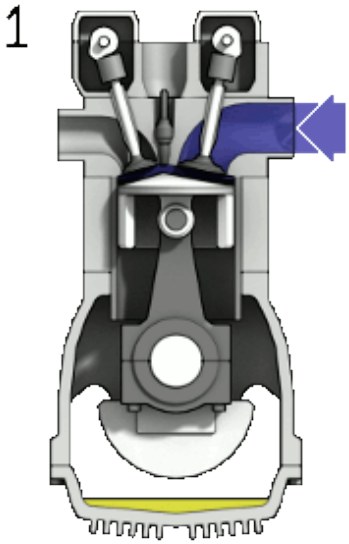
Combustion engines and electric motor

As was explained in the lecture, the first fundamental property on which electric cars differ from internal combustion engine cars is the motor.

Heat engine



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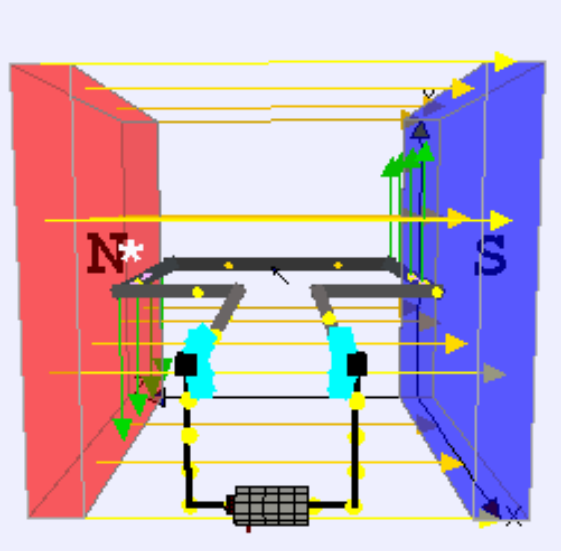
The picture shows how a four stroke engine works. This is basically the modern gasoline engine and it was invented 150 years ago.

1. On the first stroke, gasoline is injected into a chamber by opening a valve that is then closed again.
2. On the second stroke, the cylinder moves upwards and the gasoline is compressed.
3. On the third stroke the energy in the fuel is harvested by igniting it. The resulting explosion drives the cylinder down and that produces a rotating

motion. This is comparable to a bicycle, where pushing down the pedal moves the bicycle forwards.

4. On the fourth and final stroke, the energy burned is emitted.

Electric motor



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The picture shows how a simple electric motor works:

1. We take a coil of wire and make electricity flow through it, so it creates its own magnetic field. It has become a magnet.
2. We place this magnetic coil between two magnets, so one side of the coil will be pushed up and the other side will be pushed down.

3. This makes the coil turn until it is vertical. At that moment we quickly change the polarity.
4. The effect is rotary motion and what you are seeing here is a simplified direct current motor in action.

Comparison of electric motor and heat engine

Heat engine	Electric Motor	Electric motor is...
1-3 kW/kg	3-10 kW/kg	3x more powerful
0.4 kW/L	13.6 kW/L	40x smaller
5-30% efficient	93-96% efficient	3-20x more efficient
Many moving parts	One moving part	Maintenance free

Energy storage: Gasoline vs Batteries

As explained in the lecture, the main reason why the electric car didn't make it before was because of the size and weight of the battery that was needed. Back then fuel proved to be a far more efficient way of energy storage. But as you can see in the table below, battery technologies have developed to the point where size and weight are much less of an issue.

Energy source	Year	Energy (Whr/kg)	Compared to gasoline
Gasoline	1900 - 20??	12.000	-
Lead-acid	1900	10	1.200x worse
Lead-acid	2000	35	350x worse
NiMH	2000	80	150x worse
Lithium	2015	250	50x worse
Lithium	2025	400	30x worse
Lithium-air	???	12.000	same

If you simplify this table, you can easily compare how much weight you need to bring in your car to get 500 km extra range with each type of battery.

Energy source	Year	Extra weight needed for 500 km (kg)	Equals
Lead-acid	1900	10.000	Elephant
Lead-acid	2000	3.000	Rhinoceros
NiMH	2000	800	Bison
Lithium	2015	400	Gorilla
Lithium	2025?	200	Pig

Looking at these developments, the electric car will soon be lighter than the ICE car, if you take the weight of the drivetrain and the energy storage together into account. Further, as you can see from this graph from the research ("Rapidly falling costs of battery packs for electric vehicles" by Björn Nykvist and Mans Nilsson, Nature Climate Change, March 2015), battery prices are also swiftly plummeting, meaning that the electric car will soon also be cheaper.

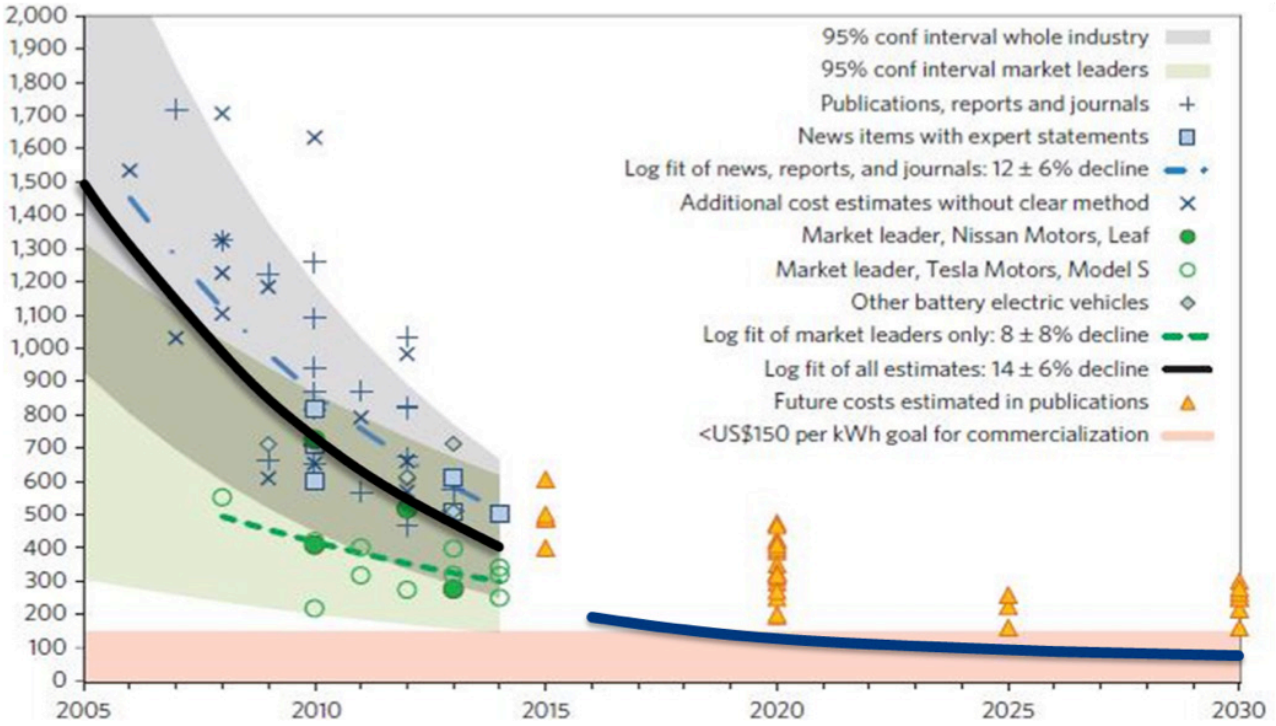

Image source: "Rapidly falling costs of battery packs for electric vehicles" by Björn Nykvist and Mans Nilsson, Nature Climate Change, March 2015.