Flexibility

Electric vehicles are *flexible* because of an obvious characteristic: most of them do not necessarily need to recharge every day. We will illustrate this with a simple calculation. In most western countries, the average daily driving distance is roughly 30 km per day. In fact, the vast majority of cars drive less than 30 km per day. A typical EV battery has a capacity of 24 kWh, which gives a range of roughly 120 km. So, on average, an EV needs to recharge every four days, which gives a lot of opportunity to shift the electricity demand.

This may seem very obvious from an electric vehicle perspective, but remember that almost all electricity demand is *inelastic*. This means that the demand for electricity is insensitive to price. People watch television when they want and they cook dinner around six o'clock - in the Netherlands at least.

The ability to shift the electricity demand in time has inspired many researchers, including myself, to look for clever ways to use this flexibility. Let's look at what a power system looks like. Electricity is generated by power plants and then transported through the transmission system to the end-users. The part of the *power grid* where the end users are connected to is called the *distribution network*, which we will look at today.

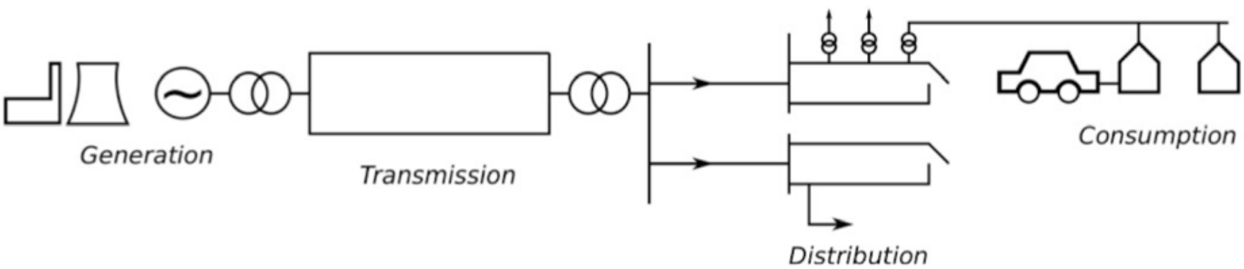
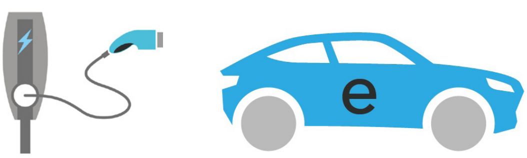


Figure: Schematic representation of the electricity system



Electric vehicles

About ten years ago, when the first electric vehicles started to appear on the roads, *distribution network operators* were getting worried that a massive adoption of electric vehicles could lead to huge costs of network reinforcements.

The figure below shows how the *average household demand*, the blue line, will increase if 50% of all households owns and electric vehicle and charges it once per day, when they come home from work. This is the red line and we see that it is a significant increase in peak demand, and probably a lot of cables and transformers need to be replaced by heavier ones. But wait a minute. Earlier in this lecture, we saw that there's plenty of room to shift the charging. So why not do this at night when household demand is low? The green line shows the resulting demand profile when electric vehicles use, as much as possible, the night to charge. Indeed, the peak demand has now hardly increased at all.

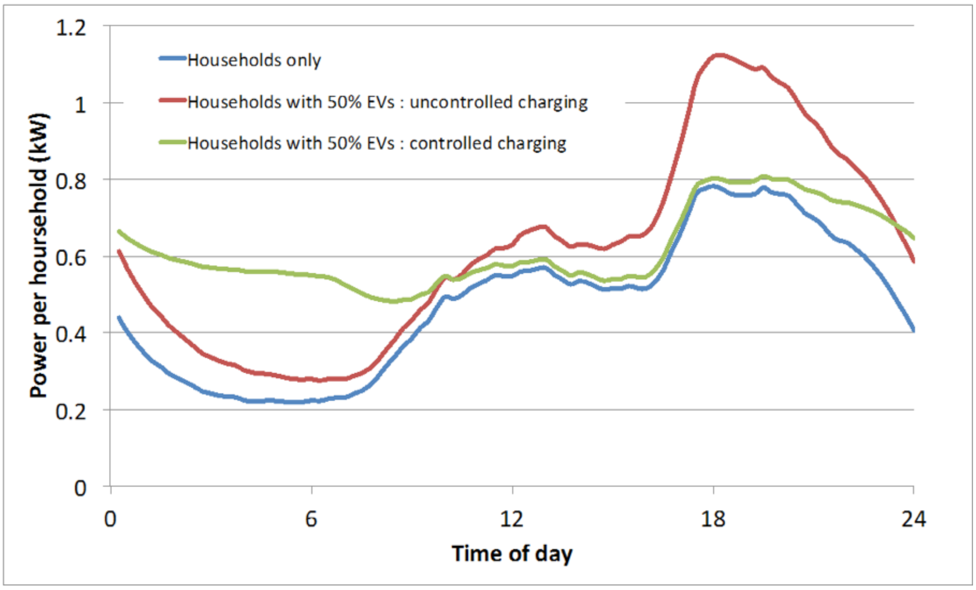
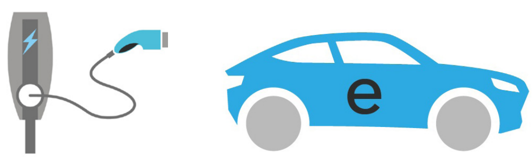


Figure: Power demand of households with and without electric vehicle charging



In a study we did with one of the *Dutch network operators*, we looked at how much money could be saved by smart charging and found that it would lead to a reduction of 20% compared to the normal charging scenario. In fact, in the smart charging scenario, the total network costs are only a few percent higher than in the case without any electric vehicles at all.

Nation level

National level If we look at the *power system* on the national level, we see that if 25% of all vehicles are electric, this has a significant impact - even on the electricity demand of an entire country! The top figure shows the normal charging scenario again, when people recharge after they come home. But like the case on the household level, here, too, we see that it matters a lot when the charging is moved to the night hours. For obvious reasons, people call this *peak shaving* and *valley filling*.

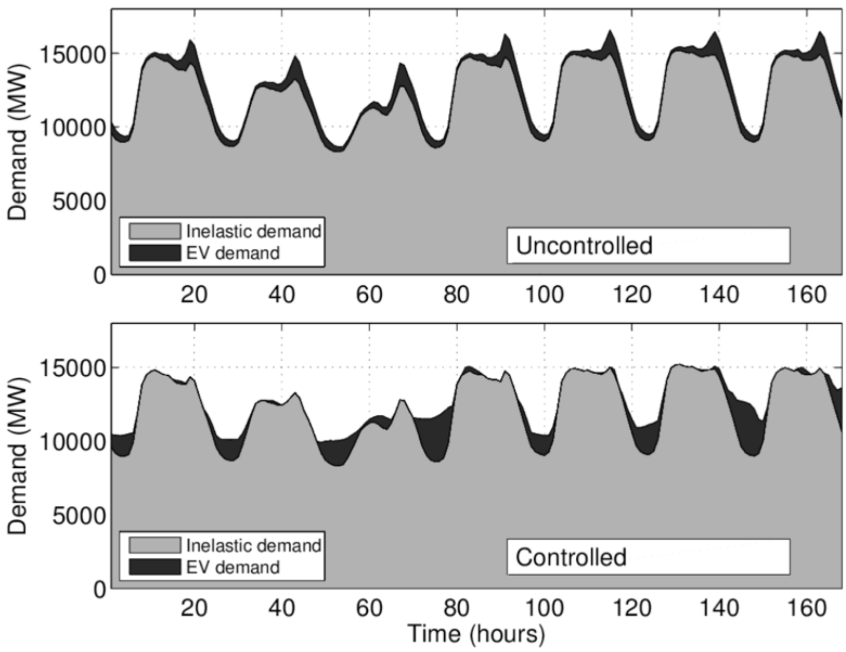
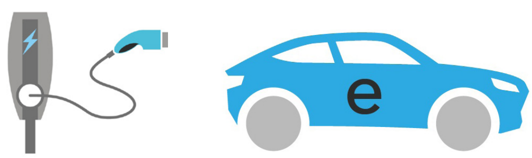


Figure: Electricity demand at the national level with and without controlled charging



Now the most elegant use of smart electric vehicle charging is when it is combined with *renewable energy*. In for example Denmark wind energy supply can outrun the demand. During these hours the price of electricity can be very low or even negative. Think about what that means: you actually get paid for using electricity!

Now this is great news for electric vehicles of course. If you can anticipate that tomorrow there will be a lot of wind and solar, then electricity prices will be very low and charging will be much cheaper. But if lots of electric vehicles are doing this, they are actually 'filling the valleys' that are created by wind energy production. An important effect of this smart charging is that, on average, electricity becomes cheaper for everybody. The reason for this is that the whole system is used more efficiently. The figure below that the electricity costs in the smart-charging scenario are roughly 15 % lower than in the normal charging scenario.

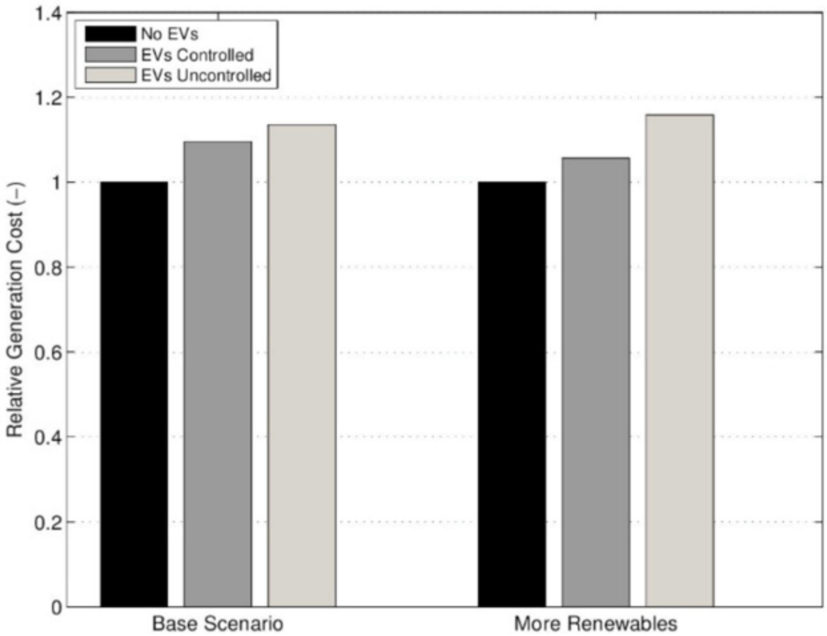


Figure: Cost of electricity under various scenarios