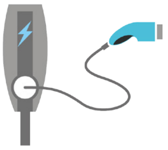
Electric cars: Policy

Lecture notes: Lecture 1.3

So, if a government strives for a future of electric vehicles powered by renewable energy in the future, what measures should it take? Given the vested interests of established stakeholders and the uncertainties about technological innovation, which policies should be designed to bring the future mobility system into being? How can they design a complete system in which the physical, social and institutional dimensions are aligned?

Three dimensions

In shaping the future mobility system, policy makers have to take into account *three different dimensions*. First, there is the physical or *technical dimension*, which includes all the technical components of the clean mobility system, such as the electric vehicles, the power generation facilities and the charging infrastructure for electric vehicles. Second, there is the *social dimension* of the system, which includes all the actors in the system, such as the users of electric vehicles, the users of electricity, the power producers, the car manufacturers, electricity and road network operators and many more. Besides the physical system, the social system is crucial in *creating the conditions* for electric mobility to unfold. We will discuss the *various actors* that play a role and how they interact with each other and with the physical system. After all, actors are the *decision makers* who decide to invest or disinvest. They have different stakes and interests, different means to influence the system, and they may differ in their willingness to take risks. The third dimension that we discuss is the *institutional dimension*. Institutions govern the interactions between the physical components, between the actors in the social dimension, but most importantly: institutions govern the interactions between the social and the physical components of the mobility system.



The physical dimension

First, we build a picture of the physical dimension: how is the system supposed to work? We assume a large share of variable renewable energy resources in the future power system, mainly wind and solar. These characteristics of the system of course differ between countries. Let’s compare for example Denmark, Germany and France. Germany has been investing a lot of money in renewable energy, both wind and solar power, but the fact is that it still relies to a large extent on coal and lignite fired power plants. France has less fossil fired power plants and more nuclear power in its electricity generation portfolio, but the share of renewable energy resources is much smaller than in Germany. Denmark, however, has made tremendous progress in greening its electricity generation portfolio, with massive investments in off-shore wind energy backed up with flexible gas-fired power plants. Already on windy days, Denmark can fully run on wind power, making the residual load zero.

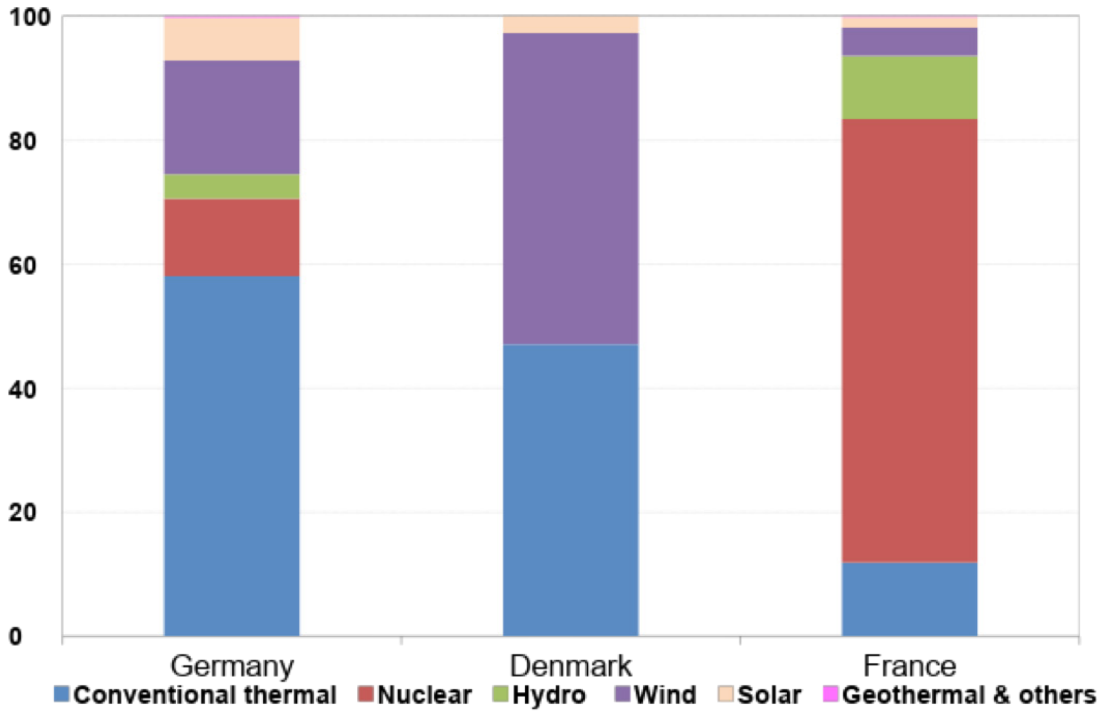


Figure: Electricity production by source in 2017. Source: European Commission

During times of excess wind power supply, the supply surplus can be exported, thanks to Denmark's cross-border connections with Sweden, Germany, Norway, and with new interconnectors to Great-Britain and the Netherlands in the future.

Residual load

However, the wind is not always blowing and the sun is not always shining. Given a future electricity system in which variable renewable energy sources play a more dominant role, *uncertainty about production* is rising, no matter how many researchers are working on improving the meteorological forecasts. So, what are the main *design variables* for countering the residual load problem? We will briefly treat the *flexibility options*: flexible power plants, demand response and storage.

Power plants

First, let us elaborate the option of *flexible power plants*: these are power plants that can be ramped up or down, to adjust their power output to the supply of electricity from variable renewable resources. Flexible power plants produce so-called *dispatchable power*, in contrast with solar panels or wind turbines. The latter are totally weather dependent and their output can only be influenced negatively, by curtailment. Not all traditional power plants are equally flexible, however. Nuclear power plants take a long time to start up and shut down and are therefore best used to supply base load. Coal fired plants are more flexible than nuclear plants, but generally are not flexible enough to supply peak power. Ramping up or down takes hours rather than minutes. Gas powered plants, however, can be started up within minutes and can provide peak power.

Currently, most national transmission system operators have a wide range of options for dispatchable power at their disposal, with different time constants, which enables them to balance generation and load even if part of the generation portfolio is weather dependent. In the future system, however, as wind and solar power become dominant in the power mix, the need for *short term flexibility* in the system will increase tremendously. The power system will need more gas-fired power plants and more *interconnection capacity* to meet the flexibility needs of the future. By the way, in a renewable energy future, the gas to fire thermal power plants is not meant to be natural gas. Instead, you can think of biogas or hydrogen.

Flexible load

A second option is to seek the required flexibility on the demand side of the power system rather than on the supply side. If the wind is not blowing and the sun is not shining, we could *reduce the demand* for electricity. This is the so-called *demand response strategy*: rather than adjusting power production, we can adjust demand to the fluctuating supply of wind and solar power. Demand response is especially relevant for electric vehicles, as the use of an electric vehicle entails a substantial electricity demand. For an average Dutch household, an electric vehicle more or less doubles the annual electricity demand of 3500 kWh per year. Many EV-users connect their vehicle at home to be recharged after office hours, which coincides with the daily peak in electricity demand. However, they only need their car fully charged the next morning. The same holds for the morning peak when people charge at the office, they only need a full car at the end of the day.

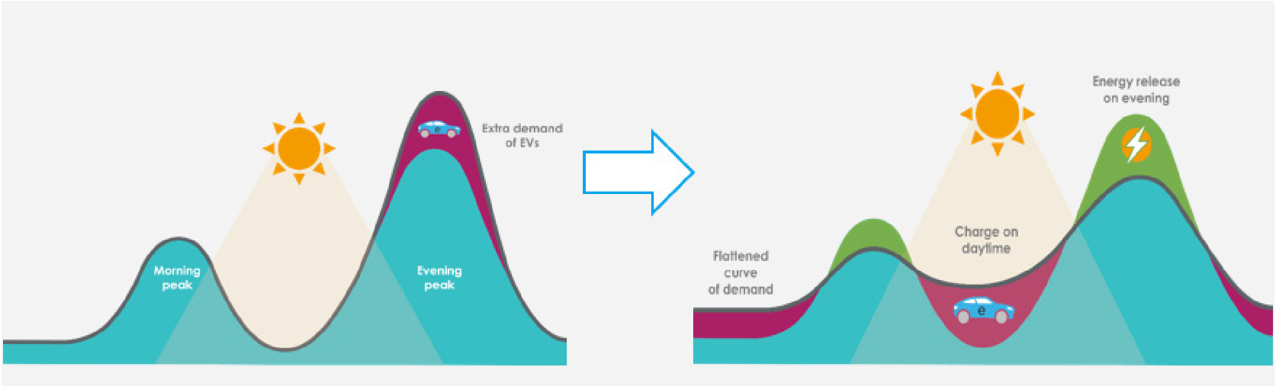
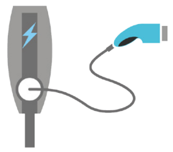


Figure: Demand response for electric vehicles



Shifting this demand to the night time or to the daytime when the sun is shining could be an efficient way to deal with the residual load problem. From a physical system perspective, this implies that we need cars and charging stations and information systems that accommodate such smart charging.

Energy storage

The third and last option to meet the flexibility needs of the future power system is the use of *energy storage facilities*. Energy storage is the missing link in the current power system, which fully relies on dispatchable power production. If we want to get rid of fossil fired power plants in the future, energy storage will be indispensable to solve the temporal variability of renewable energy resources. We will need storage when renewable power supply exceeds load, and we will need storage to supply energy when renewable power supply falls short. Possible options are using large scale batteries (Example), pumped hydro storage (Example), and chemical storage. In the latter case, excess power from renewable sources is used to electrolyze water, thus producing hydrogen (Example) that can either be combusted as a transport fuel or be used to feed fuel cells for conversion into electricity. Battery storage is expensive, but provides short term flexibility for the power system, as batteries can deliver energy back to the grid when needed within seconds or even faster.