In the first lecture we learned about destination charging, which is charging while you are parked at the destination that you wanted to go to. This type of charging consists of residential, work and street charging.

Residential charging

The most basic option in this type of charging is to use the special cable that comes with most cars and that enables you to connect directly to any household plug. This cable contains a device that communicates with the car using a simple electro technical protocol that tells the car how fast it can charge. Often this is limited to around one phase of 10 ampere. In most of the world where you have 230 volts that means 2.3kW, but in the US with 120 volts that means 1.2kW, making the direct cable relatively slow.

The second option is a dedicated home charger that allows you to use the maximum power that is available from your DSO ("Distributed System Operator" or simply "grid operator"). For example, regular households in Europe usually have three phase power at 16 to 20 ampere and 230 volts, which enables you to charge with around 12 kW. The US is one phase 120 volts but still has a wide range of amperages.

Charge points often come without charging cable attached, so they can serve cars from different manufacturers. Research shows that almost all current EV users see the ability to charge at home as a requirement for buying an electric vehicle. Since the car is usually connected overnight there is also great potential to shift the moment of charging and, if the charge point can monitor usage independently, this often provides tax advantages.

Energy storage: Gasoline vs Batteries

In terms of hardware, work chargers are very similar to residential chargers. The biggest difference is probably that most work chargers (at least in the Netherlands) have an RFID reader that makes it possible for guests to use the charge points and be billed for usage. A final difference is that often many chargers are installed in one go. This makes it more interesting to contract a specialized party to install and monitor the whole bunch. That is why most charge points at work locations in the Netherlands are monitored by a charge point operator using OCPP.

Street charging

Street charging is probably the hottest topic regarding charging in most countries. The problem is that in cities most people don't have a private parking place, so they have to park their car in the street. If they cannot charge an EV there, they will not buy an EV. Cities in the Netherlands work with a process where someone who is buying an EV can request a charging point near their home. This strategy has proven to be successful with small numbers of EVs.

Municipalities are fond of electric vehicles but not of public charge points for several reasons: they often cost money, they require more parking space and they don't fit in with the city architecture. Fortunately, these things are likely to be improved in the near future:

1. Firstly, the price of charging points is going down. Exact cost estimates are hard to give. Take a look at the Dutch cost benchmark document for some rough numbers. The important point is that public chargers are close to break-even without subsidy.
2. Secondly, the whole process of requesting and placing a charge point can be highly optimized. Some best practices that were mentioned in the lecture:
    - Ask permission from other residents in advance, so you have completed this step when a charge point needs to be placed. Preferably even designate the possible locations for charge points in advance and add the charge points itself when needed based on how many are bought in a neighbourhood.
    - Use a website that gives one shared dashboard for every stakeholder in the process. That includes the charge point operator, contractor, municipality, user and car dealer.
    - Make sure that one contractor can do all the physical work. All too often the grid operator, municipality and charge point operator have different preferred contractors, which leads to extra costs.
    - Finally, the usage per charge point is increasing due to an increasing number of cars. Originally street chargers had a turnover of about 6 kWh per day but nowadays it is 8 kWh a day on average and it's

heading to 10 kWh a day. The best spots can even do 30 kWh a day. One way to increase usage is to incentivize cars to move with a tariff per minute but so far this is only used for fast chargers.

The usage per charge point is increasing due to increasing battery size. Basically, if people have a larger battery, they will not charge every day anymore. The graph below shows how significant this effect is in a simulation carried out for one of the neighbourhoods in the SparkCity agent-based model. You can see that you need drastically less chargers if the battery increases. And since the cars charged the same amount, this translates into a larger charge per session.