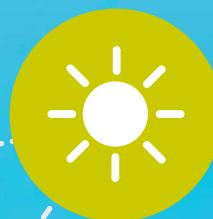


SMART CHARGING GUIDE

ENGLISH EDITION



Colophon



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4	Foreword
5	Chapter 1 Introduction
19	Chapter 2 The Challenge
37	Chapter 3 Smart Charging Section 3.1: Technical layer Section 3.2: Communication layer Section 3.3: Organisation layer Section 3.4: Legal layer
101	Chapter 4 How can we ensure Smart Charging becomes the norm?
109	Finally
110	List of abbreviations

CONTENTS

Foreword

Knowledge and innovation centre ElaadNL researches and tests the possibilities for Smart Charging. Together with our many partners, we conduct research into Smart Charging, i.e. smart and sustainable electric car charging. We believe that Smart Charging is a crucial building block on the way to a sustainable energy system for electric cars powered by sun and wind energy. But what is Smart Charging? Why is it necessary? What variants are there? Which parties play a role? How does it work in practice and what do we still have to do to make Smart Charging the norm? We looked for but could not find a publication that answered these questions. So we decided to publish this Smart Charging Guide ourselves, first in Dutch and now in English. We hope that it helps anyone who is not yet familiar with the form and function of Smart Charging, and that it provides new insights to those already familiar with it. I trust you will enjoy reading this guide, and should you be inspired, get in touch as we would like to work together in the further development and research of Smart Charging.



Arnhem, 29 February 2020
Onoph Caron, director ElaadNL

“
**Smart Charging
is a crucial
building block
on the road to
a sustainable
energy system.**
”





CHAPTER 1 INTRODUCTION

The third power revolution

The increasing importance of power in our lives: electric driving and self-generation of sustainable power.



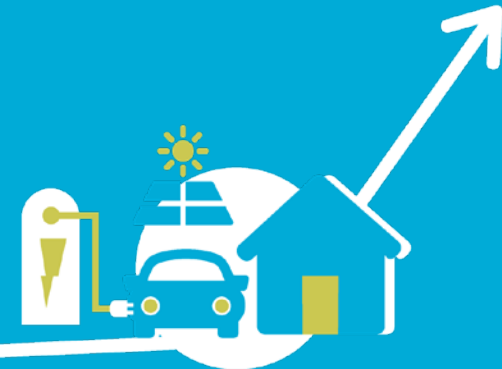
The light bulb replaces the gas lamp.

Reliable, safe and clean light enters our households in the late nineteenth and early twentieth centuries reducing our dependency on daylight for both work and life.



The arrival of household electrical appliances.

Halfway through the twentieth century, household electrical appliances come into our lives: the fridge, freezer, washing machine, iron and vacuum cleaner. As a result, household chores are no longer a day's work.



The arrival of the electric car and solar panels.

And now we're in the middle of the third power revolution, with solar panels on our roofs and electric cars on our driveways. We increasingly heat our homes with electricity, we plug in to power our mobility, and we're starting to generate and store electricity ourselves, for example in our electrically powered cars.



**2030
emission
free**

Introduction

Europe is on the eve of a major mobility revolution. In a relatively short period, we'll switch from petrol and diesel to electric driving. We're on our way to achieving one of the key Paris 2015 climate agreements: to reduce transport emissions.

In the Netherlands, this key message was translated by the coalition government into the following aim: by 2030 all new passenger vehicles must be emission-free. At the same time, electricity production is changing dramatically as we move from fossil fuels like coal and gas to renewable sources like sun and wind.

These two trends come together when charging electric cars. So, let's explore these trends a bit further.



Photo
Petrol pump

Source: Pixabay

Electric cars: nothing new!

The first fuel-powered cars were built at the end of the 19th century; they were very difficult to drive and especially to start. To start the engine, the driver had to manually pump petrol to the carburettor float chamber, set the throttle and pre-ignition manually, and crank the engine.

At the time, city officials saw the electric car as a much cleaner alternative to horse-driven transport, rather than the petrol-powered car. As early as 1907 at an international congress in Berlin, a discussion was held on the negative effect of exhaust gases on public health, as it was recognised that these contained up to 3.7 percent carbon monoxide.

Thus, at the beginning of the 20th century, electric cars were very popular: they were cleaner, easier to operate,

and much more reliable than petrol cars. Electric taxis could be found driving clients in all the world's major cities, including New York, London, and even in Amsterdam. They sometimes had battery packs that could be changed within 5 minutes. Even then, when charging the battery packs, the London Electric Cab Company took the amount of electricity available on the electricity grid into account: Smart Charging avant la lettre.

Inventors like Edison and Marconi worked on new battery technologies as an alternative to existing lead-acid batteries, developing alkaline and iron-nickel versions. In 1900, Ferdinand Porsche designed a plug-in hybrid car powered by wheel hub motors. Electric cars were also found in motor sport: in 1896, the first car race to be held in America on Rhode Island was won by an electric car.

Source

Jan Wouters 'The electric car: is it's 1914 market share achievable in 2020?'

Photo

Columbia Mark 68
Victoria electric vehicle

Source: Corbis/Hall
of Electrical History
Foundation



Our future, our history

On April 19, 1886, the very first Dutch power station, the Electric Lighting company, started generating electricity at Kinderdijk, near Rotterdam. Thanks to this new invention, street lighting could now be powered by electricity, considerably reducing the costs of lighting and extinguishing gas lanterns. Moreover, this 'new' form of power was much safer and caused less smell and smoke nuisance. The power station initially supplied power for up to 350 streetlamps in the area; not much later residents were allowed to buy energy for 12 to 15 guilders per light bulb per year. Thanks to this, the days of the old, smoky, oil and gas lamps were over; the electric bulb had arrived.

The impressive engine powering the plant ran from 12 o'clock in the afternoon to 10 o'clock in the evening. The power was supplied directly to the lamps of surrounding factories, while at the same time batteries were charged, providing power to those needing electricity outside this period.

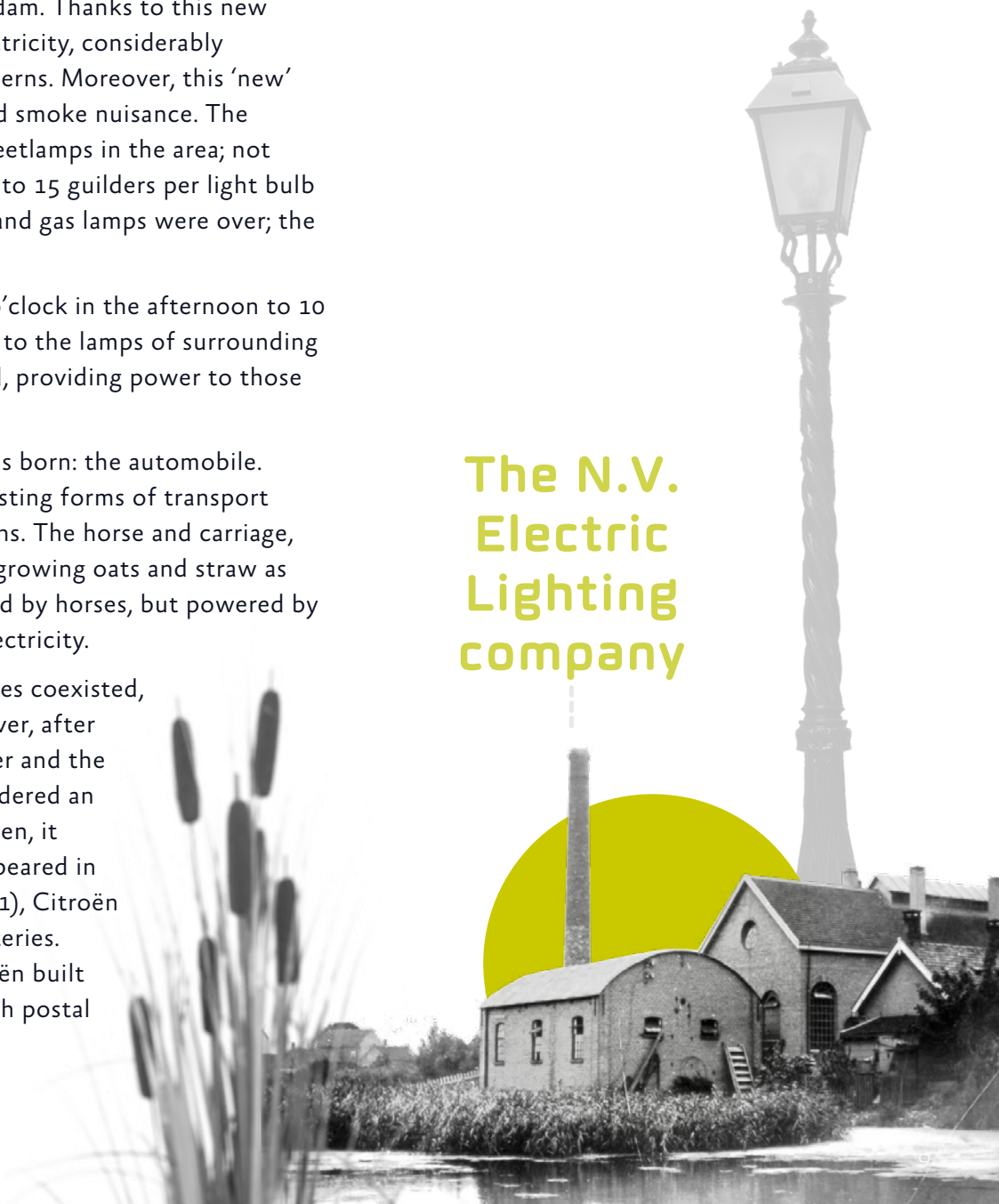
Around the same time, another pioneering invention was born: the automobile. As with the power plant, this innovation meant that existing forms of transport were replaced by a safer, cleaner and more modern means. The horse and carriage, excrement in the streets, and the hectares required for growing oats and straw as fuel were now history. This new car was no longer pulled by horses, but powered by an engine that got its energy from gasoline, steam or electricity.

In the years before the First World War, these three types coexisted, each with its own advantages and disadvantages. However, after the war, the 'internal combustion engine' (ICE) took over and the electric car almost completely disappeared. It was considered an interesting experimental concept and, every now and then, it reappeared. A second generation of electric vehicles appeared in the 1990s; manufacturers including General Motors (EV1), Citroën and Renault built electric cars, often with lead-acid batteries. Not all these models were commercially available; Citroën built electric delivery vans specifically designed for the French postal

The N.V.
Electric
Lighting
company

Photo (right)
N.V. Electric lighting
company

Source: Brush
Ridderkerk



A sustainable energy system is possible

In the future, a fully sustainable energy system is possible. The essential conditions for this are far-reaching electrification of, amongst others mobility, heat supply and major industries. All the power needed for this has to come from sustainable sources, in particular the

sun and wind. But as these sources can't supply the same amount of electricity at any given time and every season, our future energy system will have to rely heavily on adjusting demand to supply and on energy storage. This is now possible for short term solutions, days

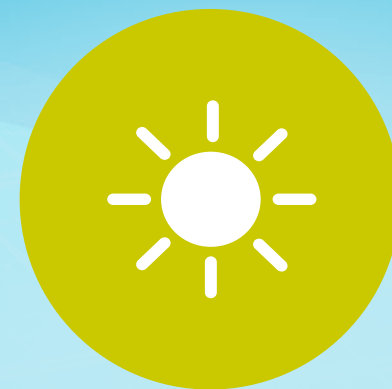
and weeks using batteries, however to bridge the seasons, we will need to store energy in a different form, for example in hydrogen.

Read more?

The future Dutch full carbon-free energy system, KIVI December 2017

Photo
Assembly

Source: Pixabay



service. However, due to the poor state of battery technology, the electric-powered car never became a commercial success. Until this century at least.

Looking back to the start of the national grid and the arrival of the car shows us how promising this time was. Once again we're in the middle of exciting times.

In the 2015 Paris climate agreement, it was agreed that countries should take measures to reduce greenhouse gas emissions in order to limit further global warming. To achieve this goal, EU member states agreed that the EU should reduce emissions by at least 40% by 2030. Ultimately, by 2050, emissions should be reduced to 80-95% of 1990 levels.

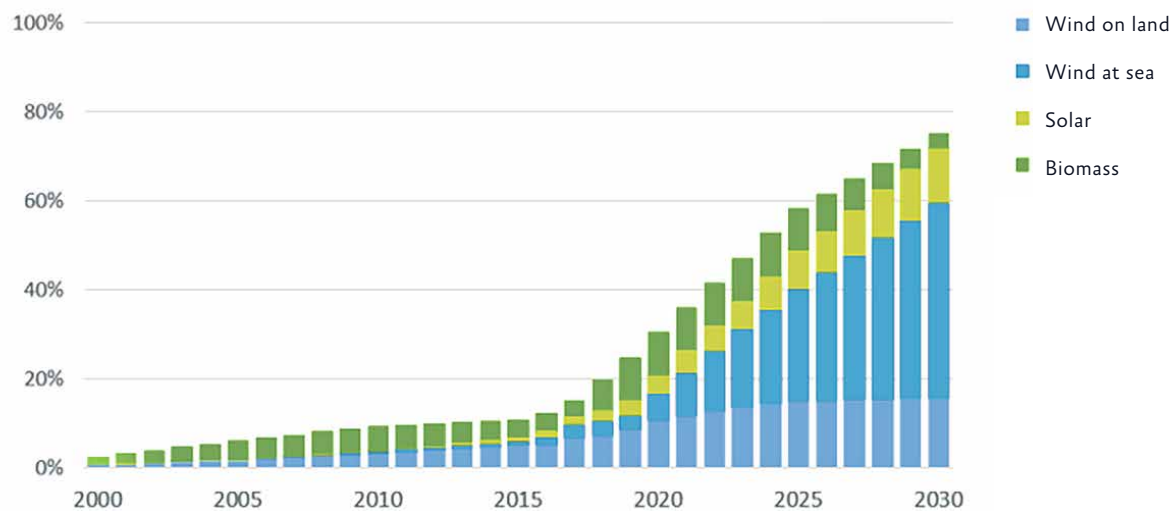
These colossal challenges for humanity require ground-breaking solutions. First of all, there will be more intensive use of sustainable energy installations such as solar fields and wind farms on land and at sea. However, we will also see an increase in smaller, local initiatives in the field of sustainable energy, for example people generating and using their own solar energy, sending their electricity back to the grid, neighbourhoods and regions independently managing a wind farm and sharing its energy.

Figure 1
Share of sustainable
electricity in the
Netherlands

Source: PBL National
Energy 2017

Photo
Landscape

Source: Pixabay



Uncertainties about future mobility

Unfortunately, no one can use a crystal ball to gaze into the future. Which trends will have the most impact?

It's difficult to predict how car use and car ownership will develop. This was also true when the city was filled with horses for our mobility and after they were quickly replaced by cars. And this is once again true. Will cars be driving autonomously? If so, to what extent and what will the consequences be? What does that mean for charging these cars? Will plug-charging still be possible, or will it be wireless?

And other questions arise about the way we use cars. How will car ownership develop? As cars remain unused most of the time, they could also be shared. If cars came when we needed them, we would only need about 15 - 25 percent of the current number of vehicles to meet our needs. However, the question is: will people, collectively, really want to get rid of their own cars?

In addition, we have to expect the unexpected. For example, car use may become so interesting that it suppresses other options: instead of getting on an (electric) bicycle or bus, you simply let the car drive you.

One thing is clear: much will change, and much more than just the engine. But exactly what and what the future brings, remains uncertain.

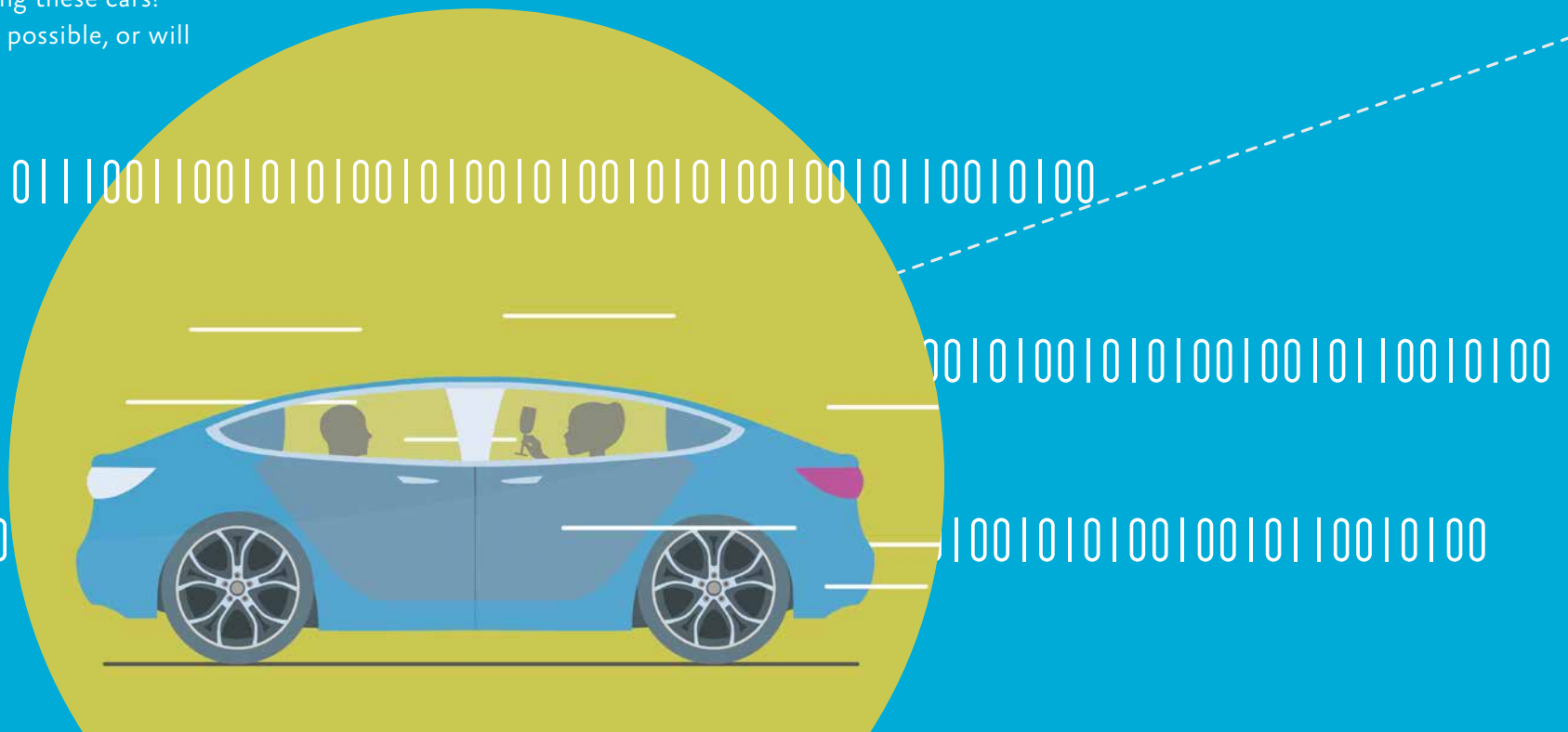




Photo
Solar panels

Source: Pixabay

One of the challenges to sustainable energy, however, is that it's not always present in the same quantities; the sun doesn't always shine, the wind doesn't always blow strongly. Moreover, energy is often needed at times other than its production. The grid will thus have to adapt to a diverse and intermittent supply of renewable energy. While to date, the supply generated by power stations has always adapted to demand, in the future, demand, e.g. when charging electric cars, will have to adjust to the supply available from solar and wind energy.

The message to new and existing car manufacturers is clear: be sustainable and clean. Cities are extremely worried about air quality resulting from petrol and diesel engine emissions. The dependence on fuel-producing countries, the CO₂ emissions associated with combustion engines and their contribution to climate change, make an alternative necessary: electric cars.

Car manufacturers are currently investing massively in developing electric vehicles. For the first time since the car appeared on the scene, electric cars have become competitive again. This is due to their rapidly improved performance, an ever-increasing range of models, and lower prices. Moreover, governments are setting massive targets for the sales of zero emission vehicles only. The rise of the electric car seems unstoppable.

“

**The car's own
revolution.**

”



Buses, trucks, boats and aircraft

Mobility electrification is about much more than private cars. In fact, electric transport is already extremely common in public transport systems. Think of trains, subways, trams and trolley buses; three-quarters of all passenger public transport kilometres are already powered by electricity. In the meantime, fossil-fuel driven buses are being rapidly replaced by electric ones, which means that by 2030 at the latest, the entire Dutch public transport system will be emission-free.

The market for electric trucks is still in its infancy and currently it mainly involves converting existing vehicles and small production series. However, a range of models from different manufacturers is on its way. As soon as manufacturers have the production capacity, we'll see a spurt in the growth of these electric trucks. The price per kilometre is expected to be so much lower that it will no longer be financially viable to continue running on diesel. It's even possible that this transformation will be even faster than what we've seen to date with electric cars.

And there's even more. The first electric inland vessels are already sailing, and the first small electric aircraft are in flight. Norway aims to have all domestic flights powered electrically from 2040. Full electrification of sea-going vessels and large civil aviation aircraft for intercontinental flights still seems far away, but small electric four-seater planes are now flying just as fast and as far as their predecessors.

Within a decade, we expect this transformation to apply to almost all business forms of mobility, especially those where many kilometres are made. Electric is not only good for the environment, it's the only way to be competitive in the near future.

Photo
QBuzz

Public transport buses are rapidly becoming electric-powered.



Figure 2a

Expected growth in electric cars up to 2035 in the Netherlands

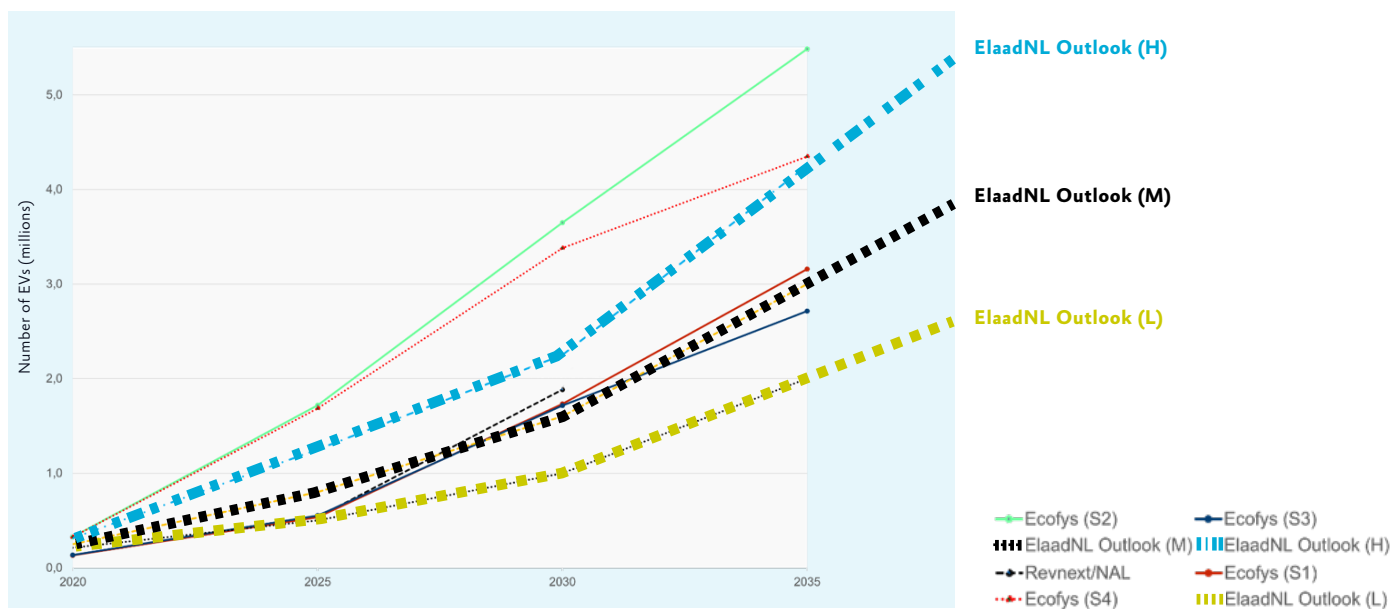
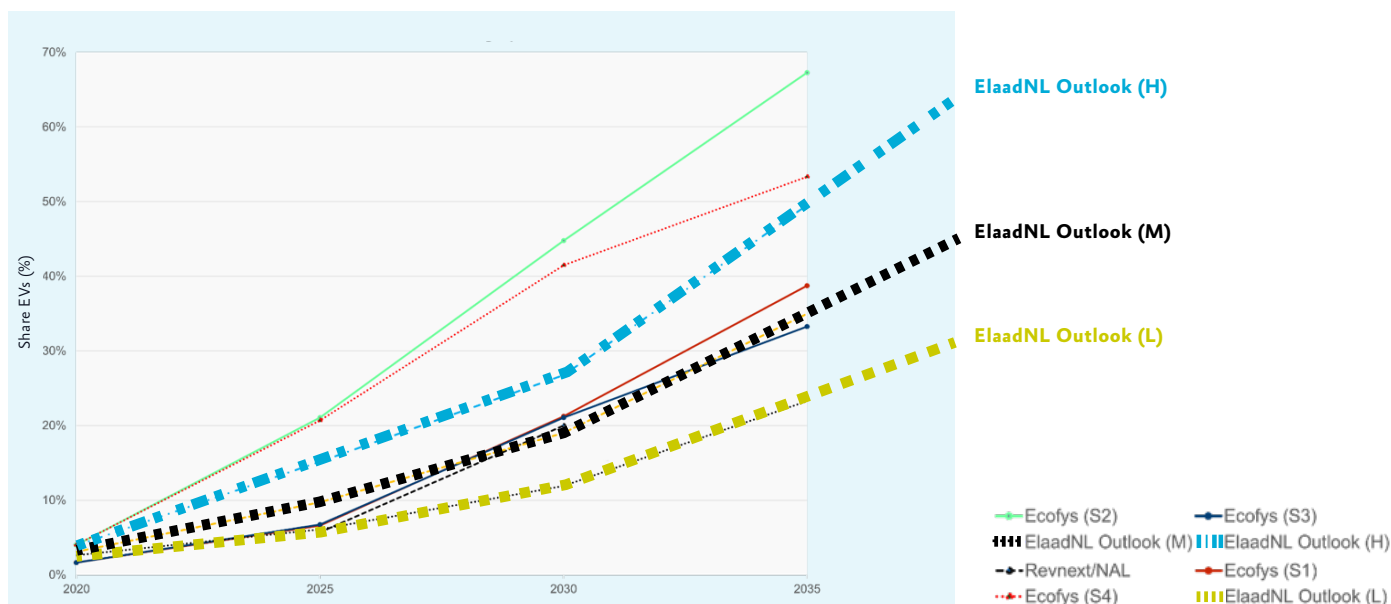


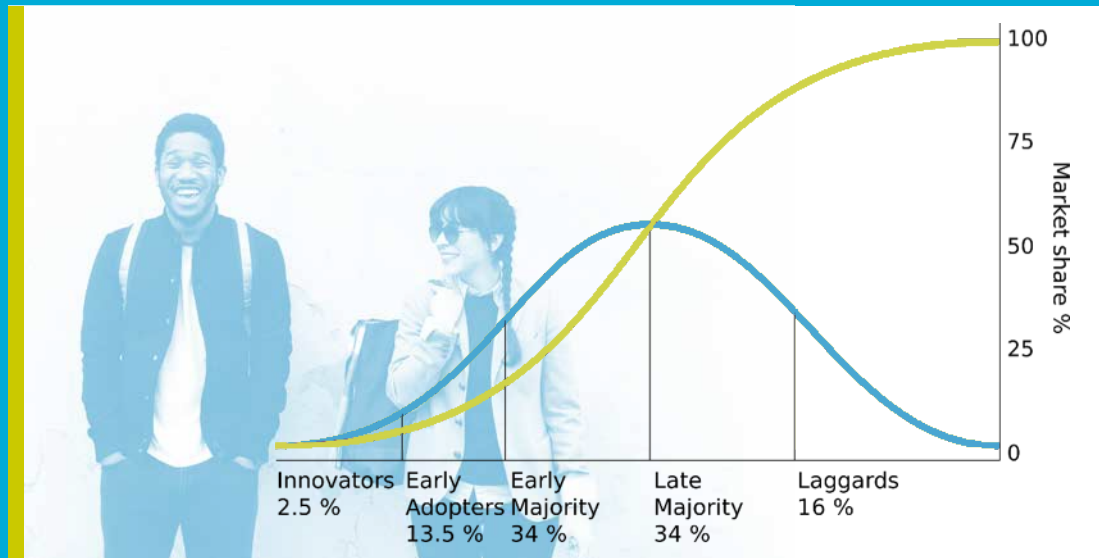
Figure 2b

Expected share of electric cars as a proportion of the total fleet in the Netherlands



It's quite clear: there will be many more electric cars driving further with increasingly improved batteries. However, all these cars have to be reliably and safely charged using the grid.

It's only the start



In the near future, we'll see a rapid growth of electric cars, from their current few percent points to 100 percent of all new cars in 2030. What you often see with the introduction of new devices is that their acceptance follows a set pattern. It starts somewhat hesitantly with the real pioneers (innovators), then slowly gains more mass (early adopters) and then takes over the market at an accelerated pace (majority). And of course, there will always be some people left behind (laggards).

Figure 3
Innovation adaption curve.

Source: wikipedia

Innovators

Around 2010, we saw the arrival of the first modern electric cars on the market such as the Tesla Roadster, the Nissan Leaf, quickly followed by the Renault ZOE and the Tesla Model S. This was accompanied by large numbers of plug-in hybrids. Cars with a plug and charging points have quickly grown from being an oddity to their current recognisable, but still modest, place on our streets. The Netherlands is an international leader in charging infrastructure development: unique in the world is that electric car drivers can use any charging point with their charge card.

Early Adopters

The electric car has moved on from its pioneering phase. Many more models are now available from a greater range of car manufacturers. They are becoming more affordable and their range is increasing. The number of charging points is also growing, both on the street and increasingly at home and work. In addition, several networks of fast chargers are being installed across Europe, with increasingly higher charging speeds. In the same period, we have seen a massive transformation to electrically-powered public transport buses, and we expect to see similar developments with electric trucks.

Mass market

Electric driving has become the standard and the street scene is determined by electric cars. Not only are there many new electric car models, the second-hand market is also electric-powered. Electric driving is cleaner, quieter, cheaper and more attractive than driving on fossil fuels. The grid is now the backbone for electric charging, in all shapes and sizes.

Conclusion

We are looking at an expected substantial growth in the numbers of electric cars and in sustainable electricity production from solar panels and wind turbines. We predict that this growth will only accelerate further. We're still at the start of what is possible, and have to prepare for the future. In the next chapter, we discuss the challenges that this presents. How can we make the electric car an integral part of a sustainable energy system?

In this booklet, we consider it a given fact that millions of cars will become electric, and that our future energy system will primarily be powered by sun and wind.

**The expectation
is that this
growth will
only accelerate
further.**

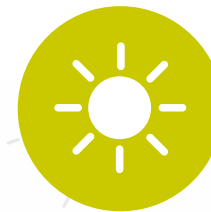


Photo
Tesla Semi-truck

Source: Tesla



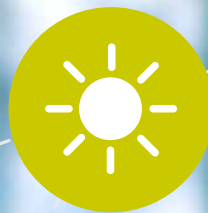
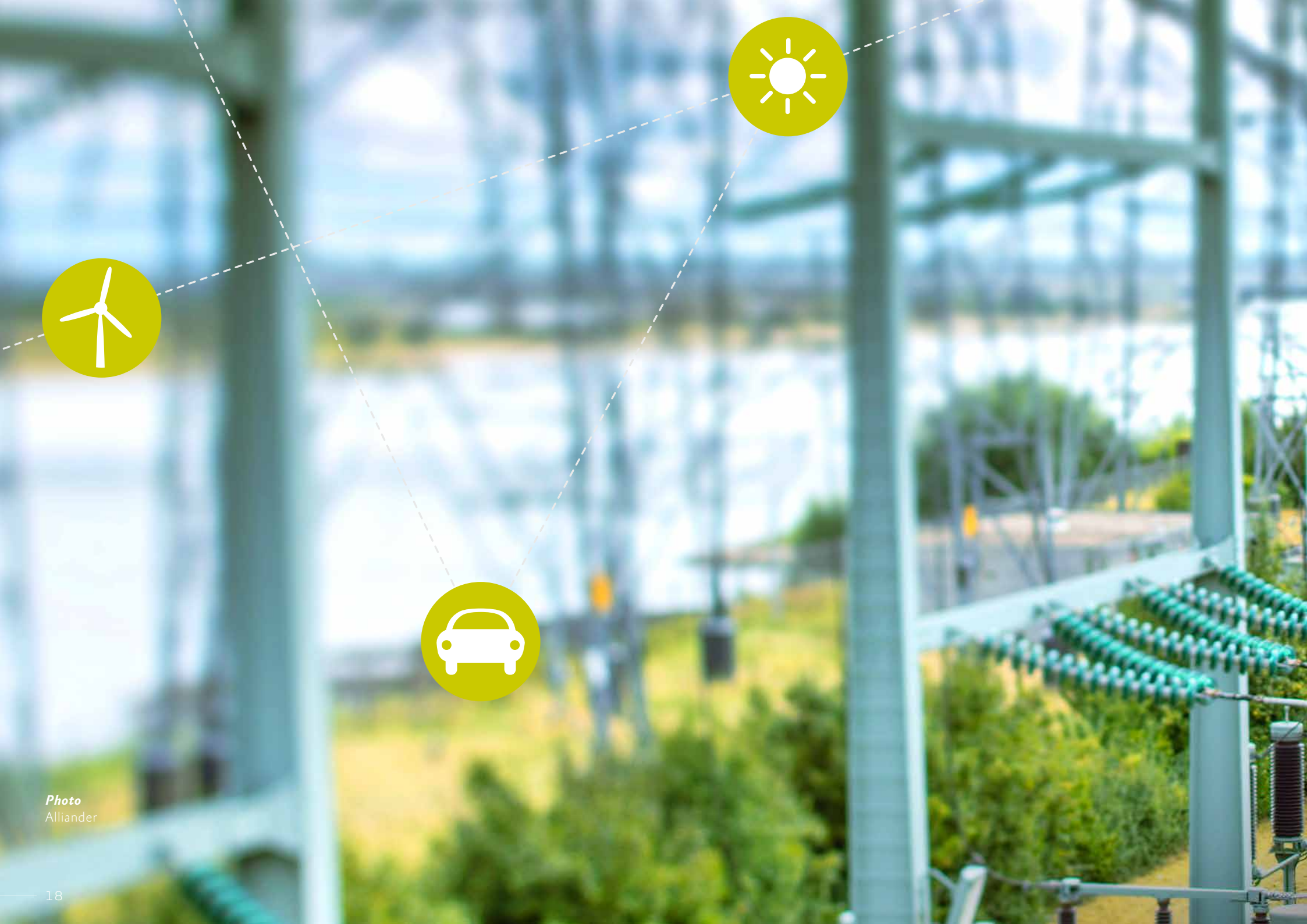


Photo
Alliander



CHAPTER 2

THE CHALLENGE

The benefits of electric driving

An electric car uses energy much more efficiently than a gasoline or diesel car. The combustion engines of the latter have an efficiency of 25-35 percent; this means that roughly two thirds of the energy contained in the fuel is lost to heat via the cooling system and the exhaust; only one third is actually used to move the car.

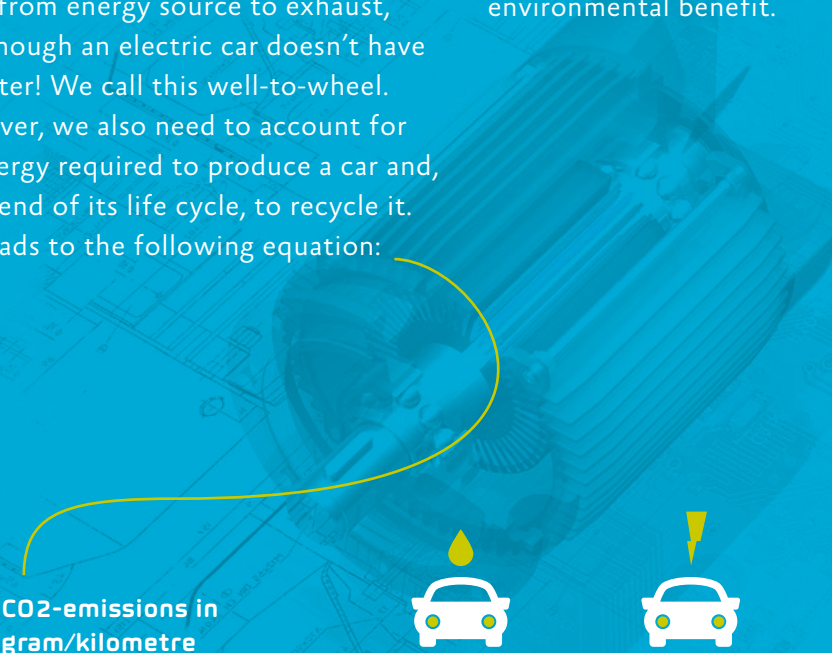
An electric motor is much more efficient and can achieve an efficiency of 90-95 percent. The energy loss in an electric car is mainly due to the fact that the alternating current (AC) from the grid has to be converted into direct current (DC) that can be stored in the battery. The energy is then converted from DC to AC again because the car's electric motor runs on AC.

*** In terms of electricity production, TNO examined two scenarios in the study: all-green electricity versus a mix of grey and green electricity, with emissions of 447 g / kWh.**

CO₂ emissions

To make a fair comparison in energy consumption and CO₂ emissions between the conventional and the electric car, we have of course to look at the entire chain: from energy source to exhaust, even though an electric car doesn't have the latter! We call this well-to-wheel. Moreover, we also need to account for the energy required to produce a car and, at the end of its life cycle, to recycle it. This leads to the following equation:

CO₂-emissions in gram/kilometre



	Diesel/petrol	Completely electric car
Oil production, refining & transport	27-30	0
Motor emissions while driving	140-170	0
Electricity production and transport (including net loss)	0	9-105*
Vehicle manufacture and recycling	46	64
Total	213-246	73-169

Even with, mainly grey, electricity produced from coal and gas-fired power stations, on balance the electric car emits less CO₂ than a gasoline or diesel car. Charging electric cars using energy from renewable sources only maximises the environmental benefit.

Photo
Motor

Source: Pixabay

Figure 4
Energy and environmental aspects of passenger vehicles

Source: TNO (2015)

Challenge

So we see and expect an enormous growth of electric cars and of electricity generated by the sun and wind.

The challenge we currently face is how to sustainably charge millions of electric cars without any problems. Can we generate enough electricity? Is that also possible from sustainable sources such as sun and wind? Can all these cars charge at the same time? And will that power be available in the right places? These are the questions addressed in this chapter.

Is there enough energy for all these electric cars?

In 2030, some people predict a fleet of 1.9 million electric passenger vehicles; a quarter of all our cars. Charging these cars will require around 6 terawatt hours (TWh) of electrical energy per year - that's 6 billion kilowatt hours! This is easily calculated by estimating the number of kilometres driven by cars in the past and the number of kilometres that an electric car can drive on 1 kilowatt hour.

Moreover, electric buses, trucks and even inland vessels and small planes will need charging. If ultimately - perhaps in 2050? - all mobility is electric, this will require around 20 TWh of electricity. These numbers raise the question: can enough electricity be generated in the Netherlands for all these electric vehicles?

Electricity production traditionally occurs in coal or gas-fired power stations and in nuclear power stations. Additionally, some industries and growers produce their own electricity with smaller production units or combined heat and power plants. In the Netherlands approximately 31 gigawatts (GW) generation power is available. Theoretically, we can produce more than 270 TWh of electricity in 8,760 operating hours per year (365 days x 24 hours). But we don't need that maximum capacity at all times - far from it: we currently use around 120 TWh of energy every year.

If 20 TWh is needed for all electric transport in 2050, an average of 2.3 gigawatts (GW) of production capacity is required; that's only 6 percent of existing theoretical production capacity.

**The challenge
we face is:
how can we
sustainably
charge millions
of electric cars
without any
problems?**

How does an EV work?

Just like a fossil fuel powered car, an electric car has an engine that drives the wheels. However, an electric car engine doesn't get its energy from gasoline or diesel, but from a battery.

Electric motors use energy much more efficiently; they have a larger torque and speed range than combustion engines. This means an electric car doesn't need a gearbox. This has many advantages: the car has more space, and it saves on

weight and maintenance. Moreover, an electric motor contains much less parts than an internal combustion engine, and no oil has to be measured or changed. An electric car therefore has lower maintenance costs.

Another important feature of the electric motor is that it acts as a dynamo: when a car slows down, for example on a roundabout, the electric motor functions as a dynamo, recharging the battery.

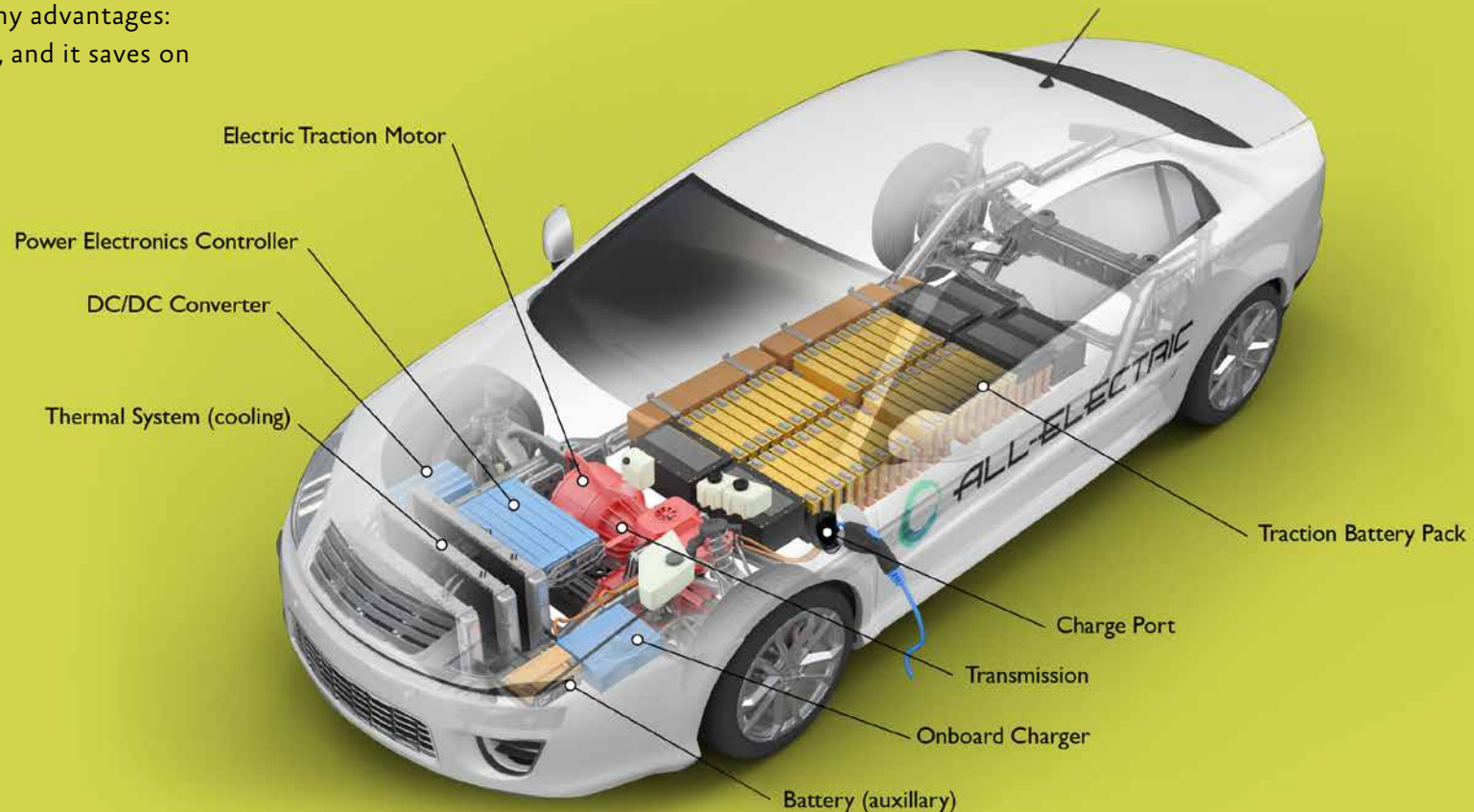


Photo
EV

Source: US
Department of
Energy

This is certainly feasible because, at the moment, more than 50 percent of our capacity is only used at peak times. If you compare the 20 TWh needed to make all mobility electric with the current 120 TWh total, that amounts to a slightly less than 17 percent increase. But this won't be an immediate change; this is about a decades-long growth in electricity consumption. This must be feasible.

Can it all be generated sustainably?

The world is changing fast. We'll stop using natural gas and coal in power plants and increasingly produce electricity through wind turbines and solar panels. At the end of 2018, we had almost 9 GW of installed generation capacity, producing 14 TWh in total. Moreover, with biomass and biogas, a few small hydropower stations and waste incineration plants all of which also produce 'green energy', in 2018 we produced a total of 18 TWh of energy from renewable sources.

Sustainable energy production is growing fast: the Climate Agreement in the Netherlands states a target of 84 TWh energy in 2030. This includes 7 TWh 'small-scale solar power projects'.

Figure 5
Solar and wind energy development in the Netherlands up to and including 2017

source: CBS (Statistics Netherlands) EnTrance (2018)



The hydrogen-powered electric car

In addition to battery-electric powered cars, there is another type of electrically-driven car: the hydrogen fuel cell car. You fill your car with hydrogen gas under high pressure, and this is used in the fuel cell to generate electricity to power the electric motor.

There are a number of claims: the car can be refuelled quickly and you can drive further on one tank. But for the time being, the supply of battery-powered electric cars is much larger, the modern versions have a comparable range, and they are much cheaper in all respects.

A major disadvantage of hydrogen cars is the lower energy efficiency of the fuel cell car. Hydrogen is not an energy source but an energy carrier and has to be produced first. At present, hydrogen is usually made from natural gas using an industrial process; this is of course not truly sustainable.

'Green hydrogen' can be produced by electrolysis, but 20-35 percent of the energy is lost. The hydrogen is then converted back into electricity by the fuel cell in the car; here too, around 35 percent of the energy remains unused. Thus, the energy chain efficiency of a hydrogen car is a factor 3 worse than that of a battery-electric car; this implies that three times as much green energy is needed for hydrogen cars.

Hydrogen may play a role in future mobility scenarios. However, for passenger cars and freight transport in the city and for many other applications, we expect battery-electric mobility to become dominant.

To close, hydrogen will most likely play an important role in the energy transition in other ways: it can be used for high temperature heating in the industry, for (seasonal) storage of large quantities of energy, and as back-up energy.

Source
WTT (LBST, IEA, World bank), TTW, T&E calculations

Cars: Battery electric most efficient by far

<https://www.transportenvironment.org/file/4477>



Source
Driving under Power

We are also going to make maximum use of sea wind with a capacity of 11.5 GW, producing 49 TWh, wind parks on land as well as large solar parks.

In other words, if we prioritise electric transport and the targets set are achieved, then there is enough electricity from sun and wind for all our mobility requirements. It's worth mentioning that the Netherlands is not even a leader in this field.

We must, however, be aware that sun and wind are not as manageable as gas and coal plants; the wind doesn't always blow and the sun doesn't always shine. The balance of the energy system will therefore change, and it can no longer be geared 100 percent to production by demand; it will partly have to happen the other way around.

The next step in this thought process is to consider whether all the cars can be charged at the same time. Two things are needed for this: all the electricity must be able to be generated at that time, and the grid must also be able to transport it. This is where we reach the limits of our current systems.

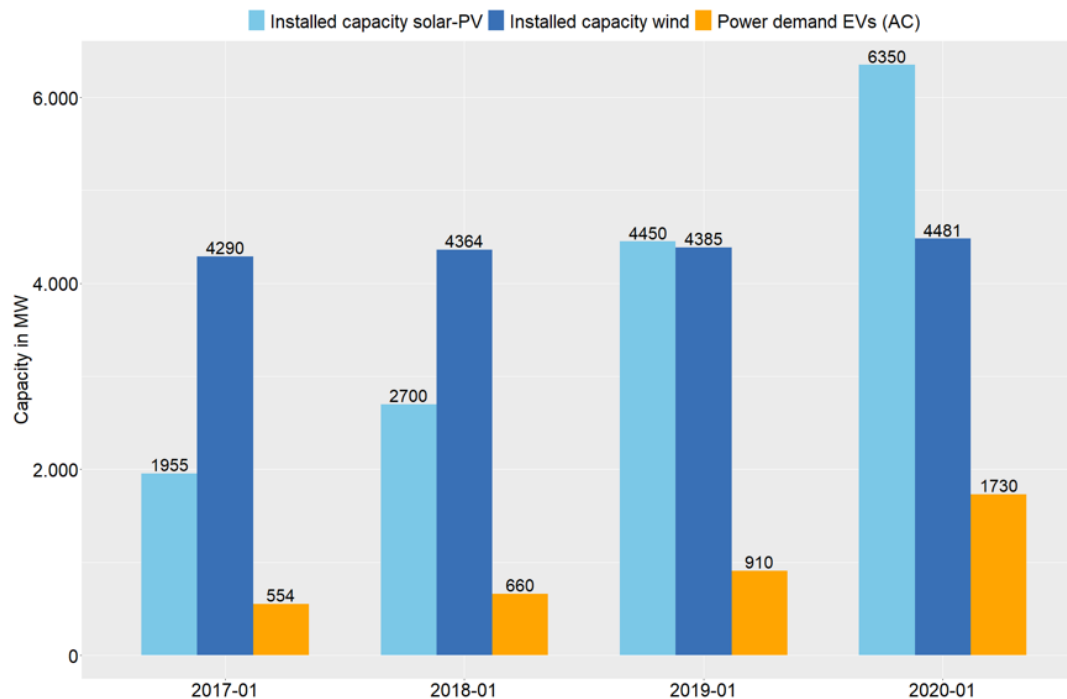


Figure 6
Generation capacity solar and wind, and the power demand of electric cars.



Too much of a good thing?

Because you can't turn the sun and wind on or off, you need a much greater capacity to ensure enough power than with traditional power plants; the latter can always step up production if demand requires it. As the share of wind and solar energy grows, there is a greater chance that at certain moments, energy production will be so large that it exceeds the energy demand. In Germany and on occasions in the Netherlands, so much electricity is produced from solar and wind sources while there is too little demand that electricity prices fall under zero. In these cases, you will be paid to tap electricity: a topsy-turvy world. This can happen at moments like a sunny Sunday afternoon with a lot of wind, as industry needs are then at a minimum. Any surpluses are often distributed abroad; however, as the Netherlands starts generating more sustainable electricity itself, it will be more difficult for Germany to rid itself of excess electric power.

Price below

€0,-

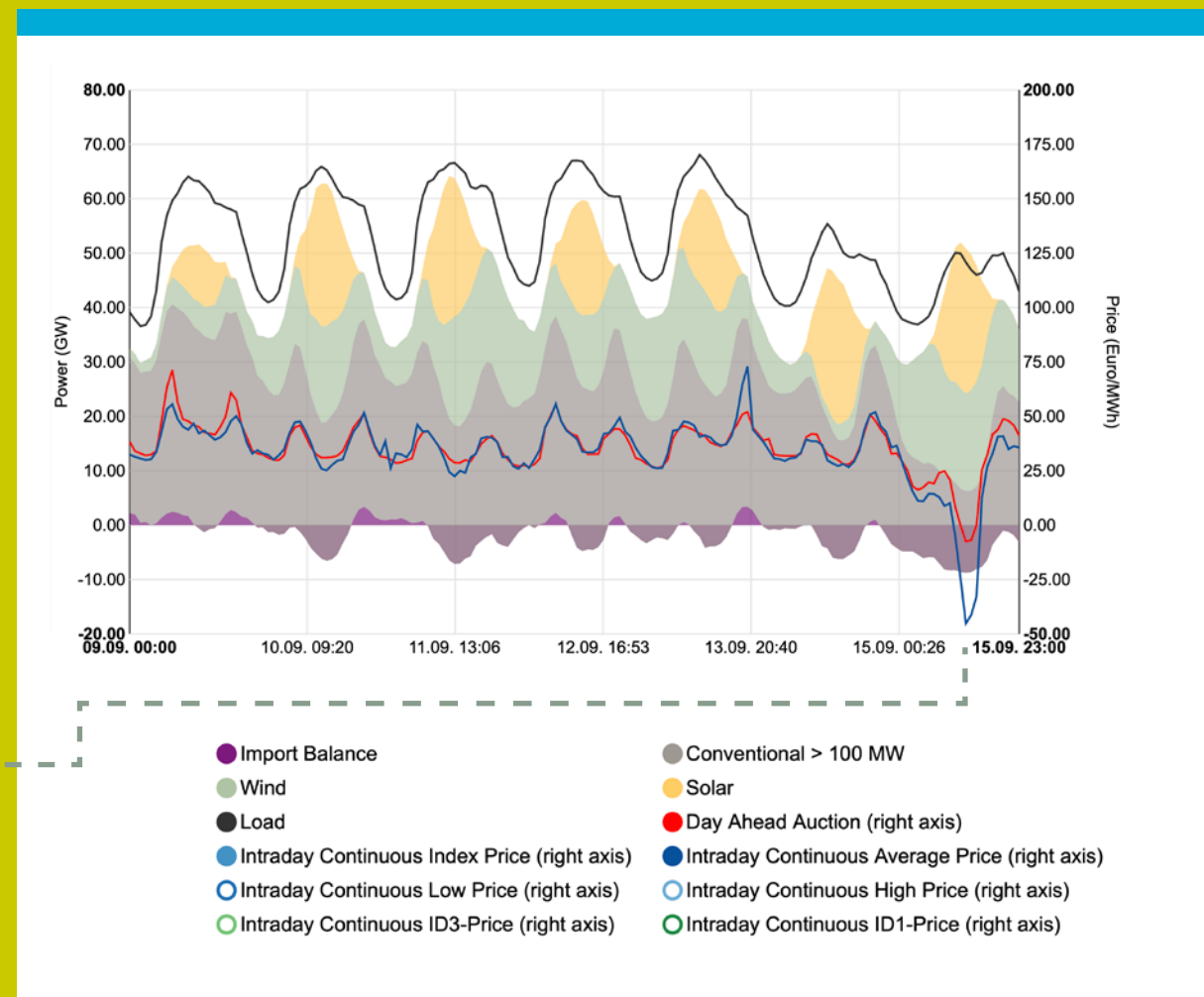
This can lead to the temporary shutdown of solar panels or wind turbines. This is called curtailment and is actually a waste of unused sustainable electricity. Fortunately there are other solutions which allow us to adjust the demand

for electricity to the supply (demand response). A good example is to charge electric vehicles at that moment.

Figure 7
Electricity production and spot prices

source :
https://www.energy-charts.de/power_de.htm

Electricity production in Germany in week 37 2019



Can we generate enough power to charge all our electric cars at the same time?

To answer this question, we have to understand that electricity must be generated at the same time it is needed. A device that requires a little bit of power over a long time has a completely different impact on the production capacity than a device that requires a lot of power in a shorter time. Think of a kettle: if a lot of electricity is required in a short time, it must also be possible to generate it at that time.

Electric cars can charge a lot of electricity relatively quickly. If, in addition, there are large numbers of cars, in the scenario that everyone drives electrically this would be more than 8 million vehicles, and they all charge at the same time, the production capacity must therefore also be considerably extended in order to meet this peak demand. That effect is much greater than the predicted growth in total electricity demand of around 17 percent.

Photo
Tennet



The electric car as pacemaker of the grid

In Europe, the electricity grid operates at a frequency of 50 Hz. This means that the voltage has a waveform that varies 50 times per second between maximum positive voltage and maximum negative voltage. This can be seen as the net's 'heartbeat'. This frequency is determined by the balance between electricity production and off-take. If there is more energy demand than generation, the frequency decreases, and if there is more generation than demand, it increases.

It is important that this 50 Hz remains constant as all our devices are designed for this. The frequency of the grid thus determines the speed, of for example an AC motor; if this deviates too much, it can start to run faster or slower than intended. Digital devices can also be disturbed by frequency changes. At the start of 2018, digital clocks were 6 minutes behind in the Netherlands and 25 other countries due to an imbalance between the energy grids of Serbia and Kosovo. If the grid becomes too unbalanced, this can lead to a failure of the entire electricity grid.

Tennet, the high voltage network operator, manages this 'heartbeat' in the Netherlands, ensuring that it remains at 50 Hz. Tennet uses different energy markets for this and with continual checks. Balancing supply and demand was a relatively simple task in the fossil-fuel past: if the demand for energy increased, some more coal would simply be incinerated in the power stations.

However, because we now have more renewable energy in the form of wind and solar energy, the supply side has become more dependent on weather conditions

and therefore less directly manageable. On the other hand, the demand side has also become more flexible. Electric mobility in particular offers an excellent opportunity to adjust electricity demand to the amount of available electricity. The charging speed can be varied and, with the latest charging techniques, you can even supply power back to the grid. In this way, the electric car ensures that our grid's heartbeat remains steady at 50 Hz. The electric car thus acts as a pacemaker for the grid!



If 8 million cars are electric and they all started charging at six o'clock in the evening (with a capacity of 11 kW), an additional 88 gigawatt (GW) of production capacity would be required at that time. That is four times as much production capacity as is currently available: we would need to move from the current 31 GW capacity to 119 GW.

However, this is a very unlikely scenario. To ensure this peak demand, we would have to develop a lot of extra wind turbines and solar parks or keep the old gas-fired power plants running for longer, or even extend them. In any case, it would be an extremely expensive solution, requiring huge investments (roughly € 90 billion) for energy production capacity only used for one hour a day.

In addition to sufficient power generation at peak demand, we would also have to get this additional power to the right place at the right time: energy has to be transported via the electricity grid from the production location to the demand site at the moment it is required.

Does the electricity grid have the capacity to transport all the electricity required for charging electric cars?

Our electricity grid has a lot of spare capacity. On average, the grid load is only 20- 30 percent of the maximum capacity. This is a logical consequence of the fact that the power grid was designed to cope with the highest expected electricity demand. This means that the power grid is only intensively loaded temporarily at peak times. Outside of these moments, the grid has about 70 percent capacity left, spread across a whole day; that's more than enough to charge all the electric cars. We have calculated that approximately 17 percent extra power is needed for electric transport; 20 TWh extra power against the current 120 TWh total.

However, if the electricity demand as a result of charging electric cars takes place mainly at peak hours, and if, at that moment, there is a high demand concentrated at certain locations, then a grid problem will arise.



310,000 kilometres of cable!

The Dutch electricity grid has 310,000 kilometres of cable connecting 8 million customers, both consumers and business. There are three different voltage levels: low (230/400 Volt), medium (400 Volt -110kV) and high (110-380kV).

The high-voltage grid is managed by Tennet, the national grid operator, and consists mainly of overhead lines on masts. The high-voltage grid has been designed to be redundant in order to minimize the risk of power interruptions: there are two groups of lines for each route.

The medium and low-voltage grids are owned by seven regional grid operators, of which Liander, Enexis and Stedin are the largest. The cables are underground. In every residential area there is a small transformer building that transforms 10,000 volts to 400 volts. The electricity cables in our streets are connected to a low-voltage rack in the transformer station.

The standard home connection has a capacity of 3x25 ampere (17 kW) or 1x35 ampere (8 kW). At times, households have peak consumption, for example when the oven, washing machine, vacuum cleaner and kettle are on at the same time. But this is unlikely to happen to everyone at the same time: simultaneity is low. As a result, the average household grid load, even during peak periods, is between 1 and 1.5 kW. For safety reasons, grid operators cater for this when installing new grids, ensuring an average of 4 kW (but not the 17 kW of the home connection). In this way, a problem only arises when everyone starts using a lot of power at exactly the same time.

Photo
Meter cupboard

Source: Enexis

Suppose you come home from work somewhere between five and seven o'clock, park the car on the street or on the driveway and start charging. Depending on the car type, the car will charge for hours and demand a capacity of 3.7 to 11 kW from the grid (in some exceptional situations even 22 kW). That's much more than an average household with no electric car; an average household has a peak power demand of between 1 and 1.5 kW. If you're the only one in the street with an electric car, there's no problem; the grid has more than enough capacity for that.



Some modern electric car models have a capacity demand of more than ten times an average home's capacity peak demand. However, be aware that this is about the capacity demand for power measured in kW, and not the amount of energy required in total, measured in kW-hours (kWh).

Some modern electric car models have a capacity demand of more than ten times an average home's capacity peak demand.

But if you're a trendsetter and the whole street starts driving electrically and everyone charges their cars at similar times, local overload can occur. This causes the power cables and the transformers to heat up, and can eventually lead to a breakdown. This type of overload mainly arises in the low-voltage grid; grid operators call this 'local congestion'.



Masses of electric cars, masses of charging points!

From 2030 onwards, all new cars on Dutch roads will be emission-free; a fleet of between 1 and 2.2 million electric passenger vehicles. And all these cars will need to be charged. According to a recent forecast by ElaadNL, between 0.8 and 1.7 million charging points will be needed: a combination of home, work and public charging points. Given the current numbers of charging points, we're looking at significant growth. This has led to an increase in connection requests to the power grid and to the necessity to power up the grid to manage the increased number of home, work and street charging points. ElaadNL's middle scenario forecasts an average annual need for more than 23,000 new connections for public charging points and hubs on the grid. In 2035, this will have risen to 45,500 new grid connections, annually.

Street charging

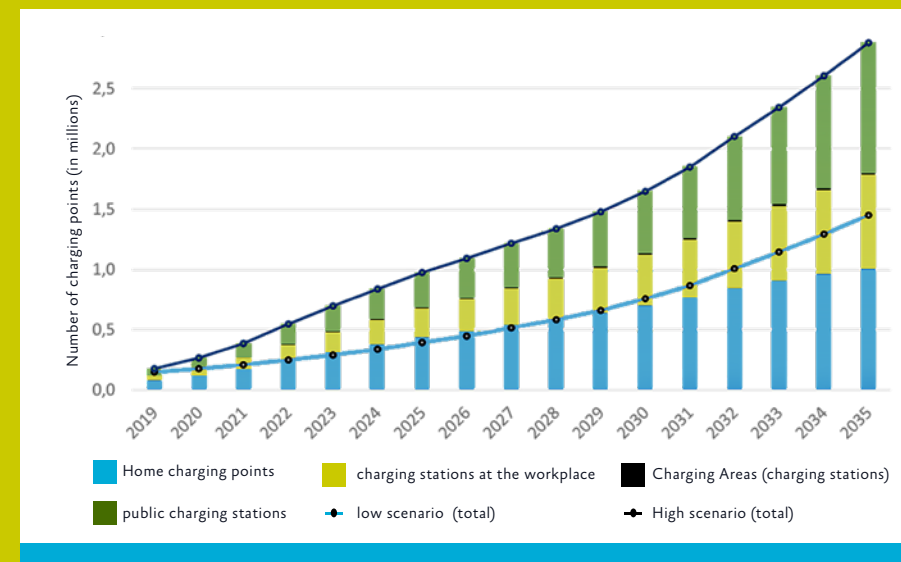
Currently in the Netherlands there are nearly 8 million households, and about a third of these have their own driveway where people can park and charge at home. This means that two thirds of all households depend on public parking spaces and therefore will be dependent on the public charging infrastructure. The construction of this charging infrastructure is complex and time-consuming. Part of this complexity is the connection to the electricity grid.

An application for connecting a new home to the grid is often known up to six months in advance. However, when connecting a public charging station to the grid, things are different.

The grid operator is obliged to ensure a grid connection is achieved within 18 weeks at the latest. For public charging points this currently takes between 10 - 18 weeks. However, if you buy an electric car, you want to be able to charge it immediately on delivery.

Grid operators, municipalities and charge point operators all have to make every effort to ensure that the work can be carried out in the required time-frame. This means freeing up and training skilled personnel, making good agreements, having a roll-out vision and placement policy with an efficient process and timely planning; all to ensure the charging infrastructure can be delivered on time.

Figure 8
Expected growth in the number of charging points in the Netherlands.





Essentially, there are two ways to deal with this: add to the grid's 'strength', i.e. installing thicker cables and transformers with more capacity, or ensuring a better distribution of the power demand. The first option is sometimes unavoidable, but it's not an attractive option for a number of reasons. Firstly, it's expensive: an estimated € 40 billion. Moreover, all streets in the Netherlands would have to be dug up with considerable inconvenience to all involved. Thirdly, the question arises as to whether this is even feasible: the Netherlands has a great shortage of technical personnel. That's why the grid operators only want to strengthen the grids in those places where other solutions do not offer sufficient help.

In many places, grid operators will have to extend the medium-voltage grid in order to be able to connect wind turbines and solar parks. The introduction of fast charging points may also lead to an increased demand from the grid; for example consider the effect of bus depots where 60 - 300 electric buses are charged overnight.

Solar cars

Will all future electric cars be equipped with solar panels so that they charge themselves? The Fisker Karma was fitted with a sunroof producing modest amounts of power. Currently, two solar-powered electric car models have been presented commercially that can drive as much as possible using their own-generated power: the Lightyear One and the Sono Sion.

No need to charge again?

That car manufacturers are trying to make electric cars as efficient as possible and integrate solar panels is an amazing development. But the potential of a

solar-sunroof is not unlimited: even on a sunny day it will probably not charge your battery at a 100%, depending off course on battery size, millage and the solar panels' production. So in most cases (if you don't live in Australia) it will probably still be necessary to charge your car's batteries from the grid or from your own solar panels, from time to time.

If solar cars were to become successful, it would certainly have a great impact on charging and the electricity grid; there would be less demand from car-charging, especially in the summer.

No need to charge again?

A few years ago, five graduate students from Eindhoven University of Technology started the Lightyear company. Their first car is the Lightyear One 'the electric car that charges itself'. The roof of Lightyear One is fitted with solar cells that provide enough energy to charge the battery during the day.

The Sion solar car is fitted with solar cells on the roof, on both sides, on the bonnet and on the rear. With a full battery, the Sion has a range of 240 kilometres.

Photo

(left) Lightyear One.
By Lightyear.

(Right) Sion.
By Sono Motors
GmbH



Although strengthening the existing grid will sometimes be necessary, the other option is generally much more attractive. We need to see whether the extra power demand from electric cars can be better distributed. In particular, spreading charging over time opens up many opportunities. You simply plug in when you get home, but thanks to smart technologies, for example, your car only charges for the required number of hours in the middle of the night when there is low demand but the wind turbines continue to turn smoothly. At the same time, your neighbour's car will be charged immediately as he has to drive a long way that same evening. So everyone on your street can plug in at the same time, but we ensure that the demand is distributed according to need, thereby preventing grid congestion. In other words, we are going to charge smartly: Smart Charging!

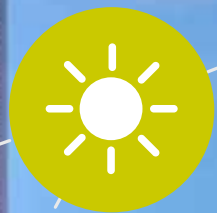
Conclusion

Generating enough power for all these electric cars has to be possible, and we will be able to generate it sustainably. But if we all charged our cars at full capacity at the same time, a huge extra peak demand would occur that we would not be able to deal with easily. We would have to install extra power plants and increase the network's 'strength' considerably, otherwise it wouldn't be possible. But if you look at everyday use, it's actually very easy to charge all these cars. The car itself must become an integral part of a sustainable energy system. So if we do it smartly and spread our charging times, we can easily and sustainably charge millions of electric cars. In other words, Smart Charging is a necessary condition for massive and sustainable electric car charging.

**Smart Charging
is a necessary
condition for
massive and
sustainable
electric car
charging.**







CHAPTER 3 SMART CHARGING

One day in the future ...

On a day in the near future, Eva gets up and gets ready for a busy day at work. She drives her electric car to work 30 kilometres away and plugs it in at the parking lot under the office. Thanks to smart techniques, the car knows that Eva has no external appointments and that there's more than enough energy in its batteries to get home. Colleagues' cars are therefore given priority when charging. Eva's car only charges when the power demand is low and the solar panels on the roof provide enough power to charge cars. When she drives home at the end of the day, the battery is almost full again. Once at home, she plugs her car in, as do most of her neighbours who have also just arrived home. Because she doesn't have to leave that evening and there's enough energy left, her car supplies her home with electricity until she goes to bed. The car starts charging again at night with electricity from a wind farm on the outskirts of the city. The following morning, fully charged with renewable energy, her car is ready for a new day!

08:00



14:00



20:00



02:00



If we want to charge all our electric cars smoothly and sustainably, we'll have to do this 'smart' with the help of Smart Charging. But what exactly does that mean? How does it work and what's involved? That's what this chapter is about. First, we look at the essence of Smart Charging and then we use the four-layer model to look at Smart Charging from different angles.

The essence

Smart Charging is essentially a control signal that indicates when and at what speed an electric car is charged. You simply plug in your car, but it may not always immediately start charging. Smart technology ensures that it is charged at the best time and at an optimum speed.

This optimisation can take place, for example, when the sun and the wind can provide enough sustainable electricity, i.e. it charges when the sun is shining or the wind is blowing. In this way, it avoids 'traffic jams' in power consumption, by charging outside peak hours or at a lower charging speed during peak hours. Another optimisation factor is price, as the car will then only charge when the electricity prices are lowest. Of course, you can also choose to start charging immediately at maximum speed.

With Smart Charging, the demand for electricity from an electric car is always adjusted to match your and the environment's needs in such a way that there's always enough power to meet the demand.

The next step in Smart Charging is using the car for energy storage for purposes other than driving. This means that you not only use power as required by the car for driving, but that your car acts as a power supply. This technique is commonly referred to as V2G (Vehicle to grid) or V2X (Vehicle to anything). Others speak of bidirectional charging or 'power recycling'. The power stored in your car can, for example, be used to power your own home, the neighbourhood, or even fed back into the grid.

“
Smart Charging
is essentially a
control signal that
indicates when
and at what speed
an electric car is
charged.
”



Incidentally, V2G is not yet a standard electric car feature. A number of Japanese cars can do it via a DC charging station where the car's direct current (DC) is converted to alternating current (AC) for use at home or on the grid. Until recently, that was only possible with a fast charging station. Bidirectional charging and discharging via an AC charging station, currently used for standard charging, is still under development. Renault ZOE's are now being co-developed in a pilot project in Utrecht that can discharge using AC charging points.

For both variants of Smart Charging - adjusting the demand to needs or using the car as a power provider - a lot has to be done to ensure that this will work properly.

The four-layer model

For Smart Charging to work well, it must, of course, be technically feasible. Both communication and IT must match and be secure. Moreover, rules and regulations have to be in place to make it possible from an organisational and legal point of view to ensure that stakeholders can work together.





The elements of the Smart Charging four-layer model:

1. **Technical layer**
2. **Communication layer**
3. **Organisational layer**
4. **Legal layer**

The **first layer**, that of technology, is about the components that make Smart Charging technically possible, the possibilities and limitations that technology provides, and the data. For example, somewhere in the Smart Charging ecosystem there must be components that send and receive a control signal. If there is no intelligence anywhere in the hardware, you couldn't charge smartly other than by plugging in or plugging out at the right times. But more than the fact that nobody wants to go out in the middle of the night and plug in their car to harvest low-priced power from wind turbines, this isn't what we mean by Smart Charging.

In other words, the devices must contain smart components – the charging station and the car, or via another route such as a home energy management system. The technical layer is also about data: data on power consumption, battery state of charge, et cetera. The technology also determines the bandwidth within which Smart Charging is possible: the power used to charge the battery that enters the Smart Charging point from the grid can never be more than the maximum transmitted at every link in the chain.

The **second layer** is the that of communication between devices. This specifies which routes a Smart Charging control signal can follow and which languages ('ICT protocols') are required. The devices - charging station, car, or other route - must not only have components that can communicate with the outside world. They must also be able to 'talk' to each other in the same language so that they understand each other. And that communication must be secure, so cybersecurity is a crucial feature in this layer.



Technical
layer



Communication
layer

Direct and Alternating current – AC/DC

Source
AC/DC: The Savage Tale of
the First Standards War
Tom McNichol, 2013

Electric car batteries, in fact all batteries, work on direct current (DC), while electricity from the socket is alternating current (AC). During normal charging, an inverter in the car converts AC to DC. With fast chargers, the inverter is in the charging station and the battery receives DC from the charging station. Note that the plugs and cables for fast charging are different from those used for normal charging.

WAR OF THE CURRENTS

Inventor Thomas Edison had to set up a completely new system for generating and transporting electricity in order to make his light bulbs burn. He did that with direct current (DC). But soon after, a competitive system was introduced: the alternating current (AC) system. Later on, another inventor, Nikola Tesla, became embroiled in this and a fierce battle erupted over which system was to become the standard. This was brilliantly won by the AC camp as this enabled electricity to be more easily transported over larger distances. However, this was only made on the understanding that DC would always remain important in applications such as batteries. All modern electronics also work on DC. Currently, there are those who advocate the entire grid to become DC.

A black and white portrait of Nikola Tesla, a man with a mustache, wearing a dark suit and a white shirt with a high collar. He is looking slightly to the right.

AC

A black and white portrait of Thomas Edison, an older man with white hair, wearing a dark suit, a white shirt, and a dark bow tie. He is looking directly at the camera.

DC

The **third layer** is about how we organise it all. Who sends control signals, with which profiles, and with which strategies? And how do these all come together? How can we regulate this?

Several parties have a stakeholder interest in Smart Charging: the motorist, the car manufacturer, the charging station operator, an Electric Mobility Service Provider, the municipality, the grid operator, the energy supplier, a possible 'aggregator', et cetera. These interests can sometimes run parallel, but can also be conflicting. So we have to set up the system in such a way that it can handle stakeholder needs. In addition, a key aspect is that the system that actually controls charging makes intelligent combinations of the input from the diverse group of stakeholders. Intelligent and automated decision-making is needed to satisfy all the stakeholders' needs.

The **fourth layer** is the legal set of contracts, laws and regulations, i.e. the contracts that the parties draw up and the laws and regulations within which they operate. Smart Charging starts with an agreement between the person who can provide flexibility (for example, charging an electric car later or less quickly) and the person who needs this flexibility. Agreements can therefore vary from long-term in the form of an annual contract, or be more flexible. Worth noting here is the issue of 'who plays which role'? What is available on the market, and what about public parties? Can grid operators, for example, pay for flexibility or offer other contracts (including flexibility) and can they intervene if there's a risk of overloading the grid? At the moment the law provides for room for experimentation so we can gain experience with various forms of flexibility, especially related to Smart Charging. However, structural solutions are still limited at this moment in time.

These four layers together form the key components of the Smart Charging ecosystem.



Organisational
layer



Legal
layer

Several parties
have an interest in
Smart Charging.

The third generation of electric cars is on its way!

Two major barriers to buying electric cars are rapidly disappearing. Range anxiety (how far can I still drive?) is now on the return. You can charge your car faster, there are increasing numbers of charging points, and the batteries have an ever increasing capacity. At the same time, purchase costs are falling: the threshold is now much lower.

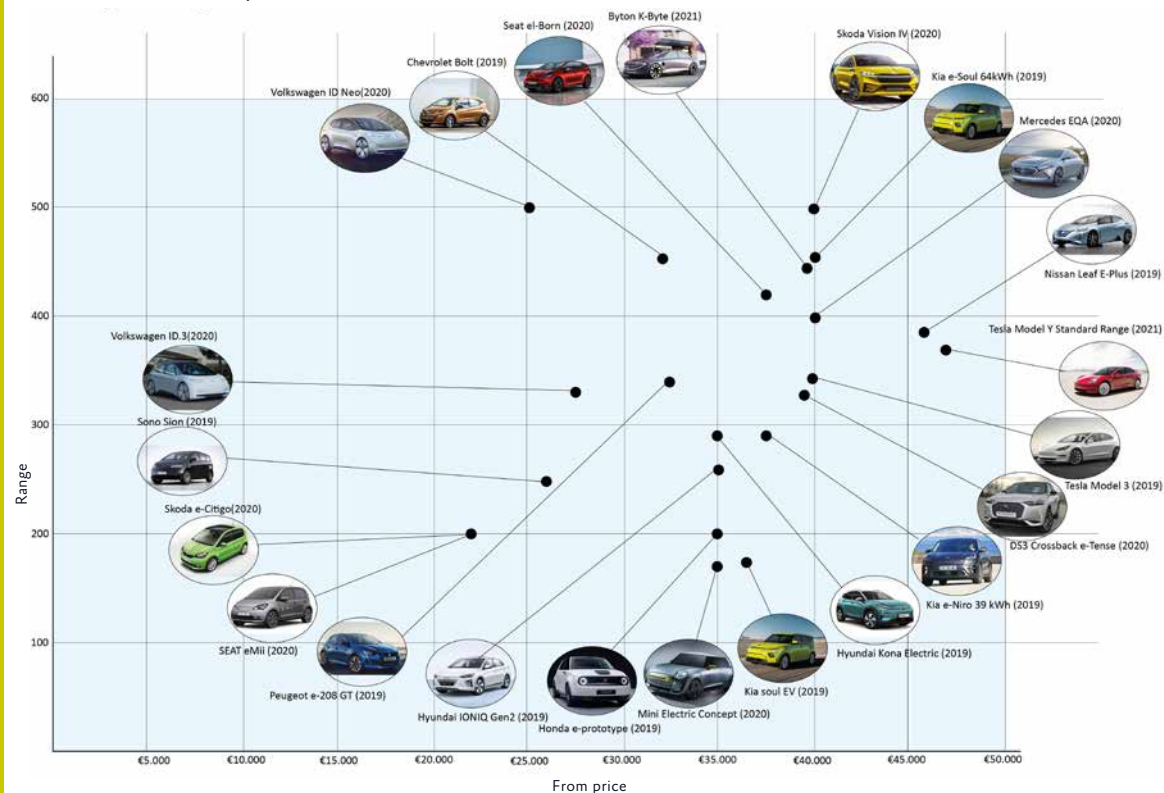
An example; the Nissan Leaf was introduced in the Netherlands eight years ago with a 24 kWh battery and just over 100 kilometres radius. It was pioneering at the time, but this was not enough to convince the masses. The second generation of Nissan Leaf is now available with a 40 kWh battery and a range of over 200 kilometres; more than double the previous version. There is now a 'plus version' with a battery capacity of 62 kWh.

The electric car of the future will have many fewer restrictions. The expectation is that by 2025, the third generation of electric cars will have sufficient range for everyone and that recharging will only take 15 minutes, if necessary. These cars will then be the standard and equivalently

priced to petrol powered cars, while they are much cheaper to use. Because car manufacturers see these vehicles as key models, production is fully underway and the current longer delivery time for electric cars will be a thing of the past.

Thus, in the near future, electric cars will have become the best option. The second-hand market will also pick up: second-generation electric cars will be affordable for starters or as a second car, in addition to the increasing numbers of shared (second) cars.

Announced EVs up to 50.000 euro



Source
NVDE

3.1 Technical layer

There are two main parts to the technical layer: components and data. These determine whether Smart Charging is possible and within which bandwidth. Three elements are crucial to this: the ability to send a control signal, the available data, and the maximum charging capacities.

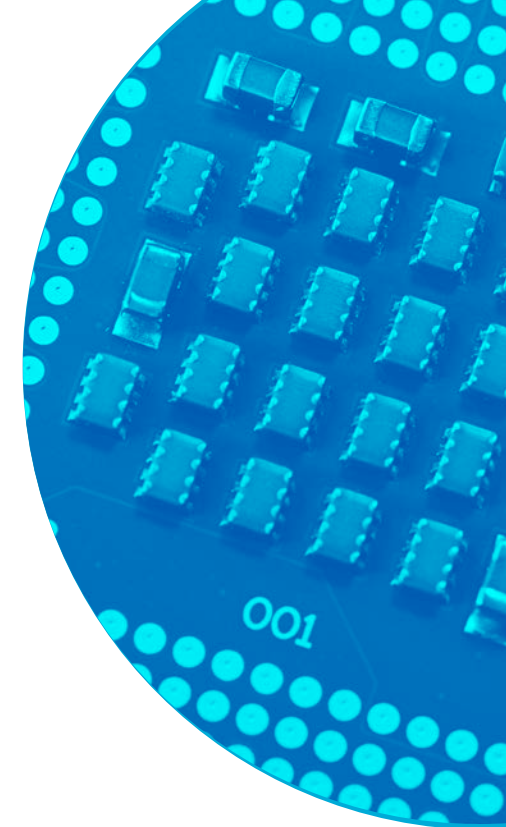
Where's the intelligence?

As noted earlier, for the crucial element of control you need intelligence embedded somewhere in the Smart Charging ecosystem. This intelligence comes from a Smart Charging Management system which can be found in a number of places: the car, the charging station, a home energy management system, or even the grid. It can operate as a stand-alone system and can make independent decisions. But the intelligence can also be located more centrally; in this case the signal passes through a communication connection with the local components. The advantage of centralised solutions is they can combine information across locations.

Intelligence in the Smart Charging ecosystem

	Local stand-alone	Central to the cloud
Car	Battery management system	Connected car
Charging station	Controller	Back office system
Power grid	Smart meter & local smart grid	Grid management system operators
Related energy systems	Home energy management system & Building energy management system	Online energy management platforms

Smart Charging is possible with any of these solutions. Experience with these options varies considerably; most research data currently comes from Smart Charging stations in the public arena.



Expected rapid growth in fast charging stations

Fast charging stations and regular charging stations complement each other. Fast charging is faster but more expensive, and isn't (yet) possible at your front door, however they're both indispensable if you drive further than your car's battery limit. In addition to the expected large growth of regular charging stations, we also predict substantial growth in the number of fast charging stations.

At this moment, e-drivers can fast-charge at about 200 locations in the Netherlands, with a total of 1,000 fast-charging stations. We expect this number to more than double between now and 2025; an eight-fold increase may also be feasible.

The market is already diverse; different providers have all entered this market with different motives, ideas and considerations. We see charging stations operated by car manufacturers like Tesla, by independent providers like Fastned, but also by the 'traditional' petrol stations that want to serve electric cars and their drivers. In addition, a group of entrepreneurs are adding fast charging

to their service, for example, roadside restaurants and supermarkets.

The power generated by a fast charger is also rapidly increasing; the latest electric car models can now charge at 350 kW.

- Promising location (50-100 kW)
- Promising location (175-1750 kW)
- Promising location (700-1750 kW)
- Existing location (50 – 150 kW)

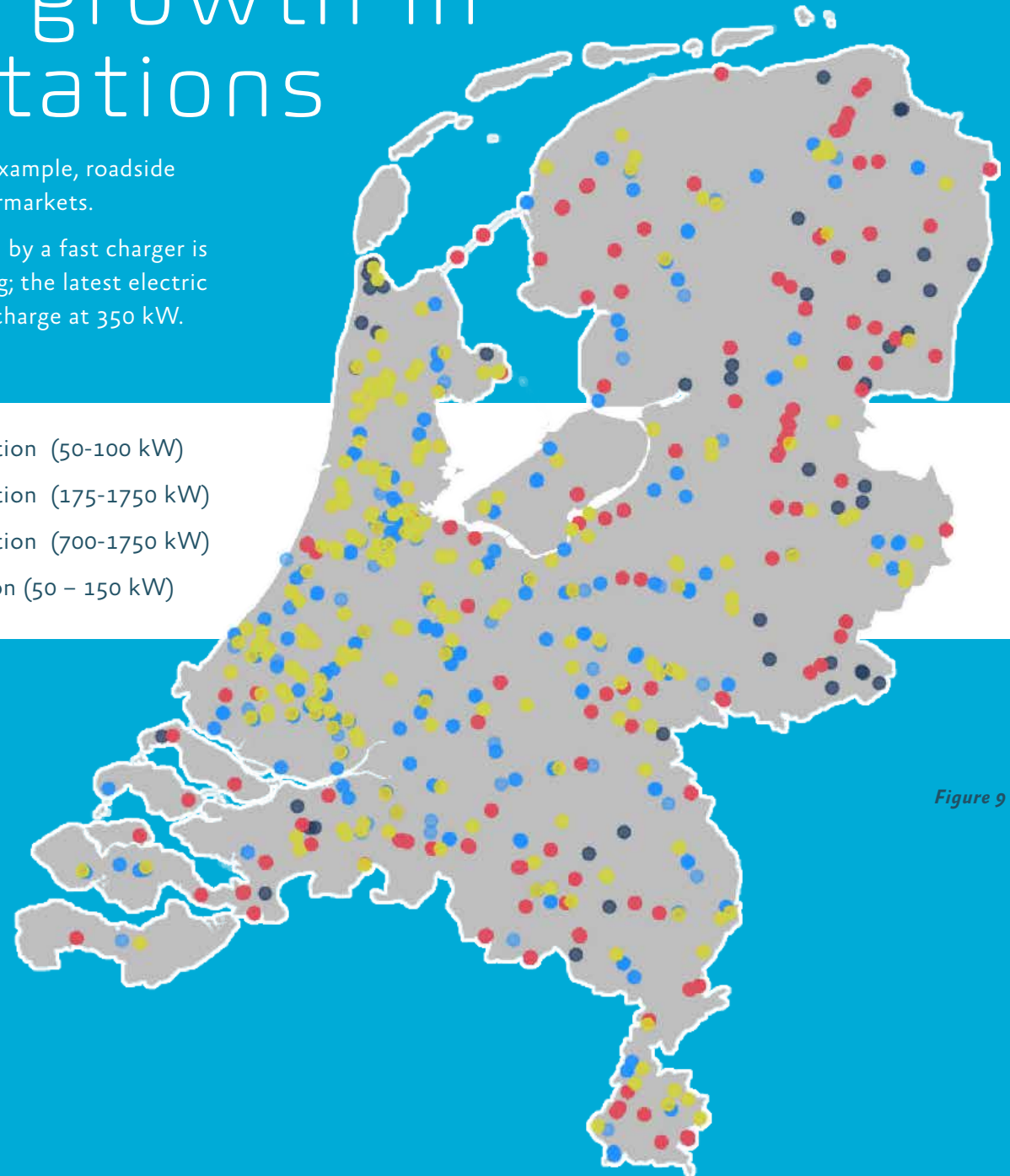


Figure 9

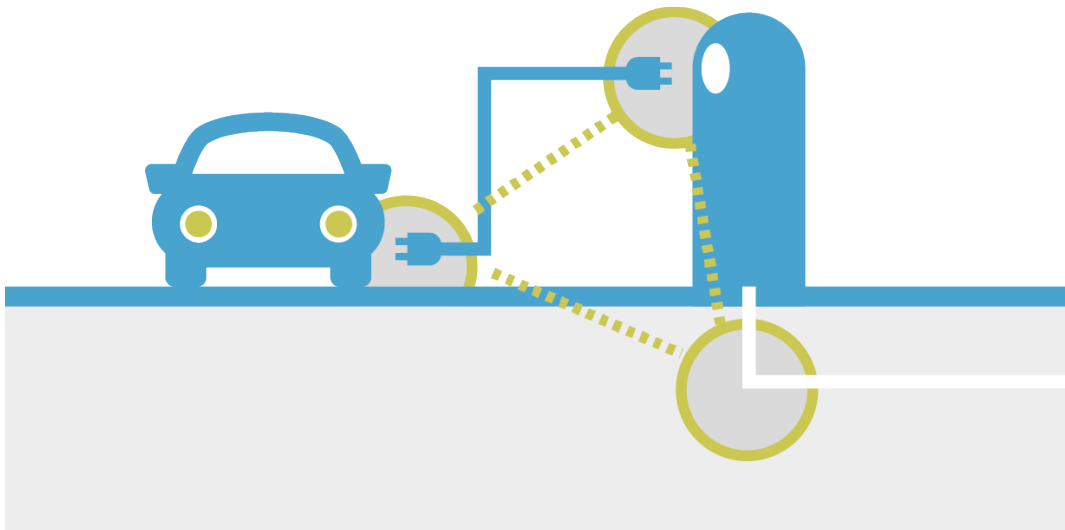
But recently also pilot projects have started with Smart Charging in home - and office environments. And other options with intelligence in the car (connected car) or in the smart meter are being investigated.

How fast can you charge?

Smart Charging also depends on the **maximum charging speed available**, as this determines the bandwidth of charging capacity. Charging speed is expressed in kilowatts (kW) and depends on a number of factors.

Firstly, the car has a maximum charging speed which differs between models and brands. Secondly, the charging point determines the maximum available power which depends on the type and whether several cars are charging at the same time. And finally, the connection from the charging station to the grid has a maximum capacity. Therefore, the charging speed is determined by the weakest link in the chain.

Thus a car's own capacity, the charging station, or the connection to the grid determine the car's charging speed at any given moment in time.



Smart Charging also depends on the maximum charging speed available, as this determines the bandwidth of charging capacity.

Wireless charging!

Parking with wireless, plug-in-free charging, or even charging while you drive on a specially equipped road: these are only two examples of a number of experiments with wireless – induction charging techniques.

How does wireless charging work? It's based on two magnetic coils: one in the ground and one under the vehicle. Inverters ensure that a high frequency current flows through the primary coil into the ground; this connects to the secondary coil in the car; a gap of 15 centimetres between the coils is possible. The car's coil connects to an inverter, which then charges the battery. It's an efficient process, above 90% is achievable. However, this is still lower than plug-connected charging where returns of more than 95% are possible.

Car manufacturers are still fully committed to cable-charging. With the advent of larger batteries and therefore a greater range, there is less need to plug in after every ride, and for really long distances, fast or superfast charging should be possible. Currently, cable-charging is still the best option.

However, it would be an advantage for many not to need a daily home-charging session. Moreover, in the context of Smart Charging, it would be best to have cars continually connected to the grid as often and for as long as possible. Wireless charging makes this feasible.

In the future, we would expect self-driving cars to be able to self-charge; wireless charging would seem the best way to facilitate this. Another great advantage of wireless charging would be the reduced impact on our streets, as fewer charging points will be needed.

At the moment, wireless charging is only possible by making post-purchase

adaptations to existing electric cars. BMW is the only manufacturer to officially offer a wireless charging system. Currently, high charging capacity experiments are being carried out on electric buses. However a so-called pantograph looks more promising for high power bus charging.



Photo
Rotterdam
tests wireless
charging

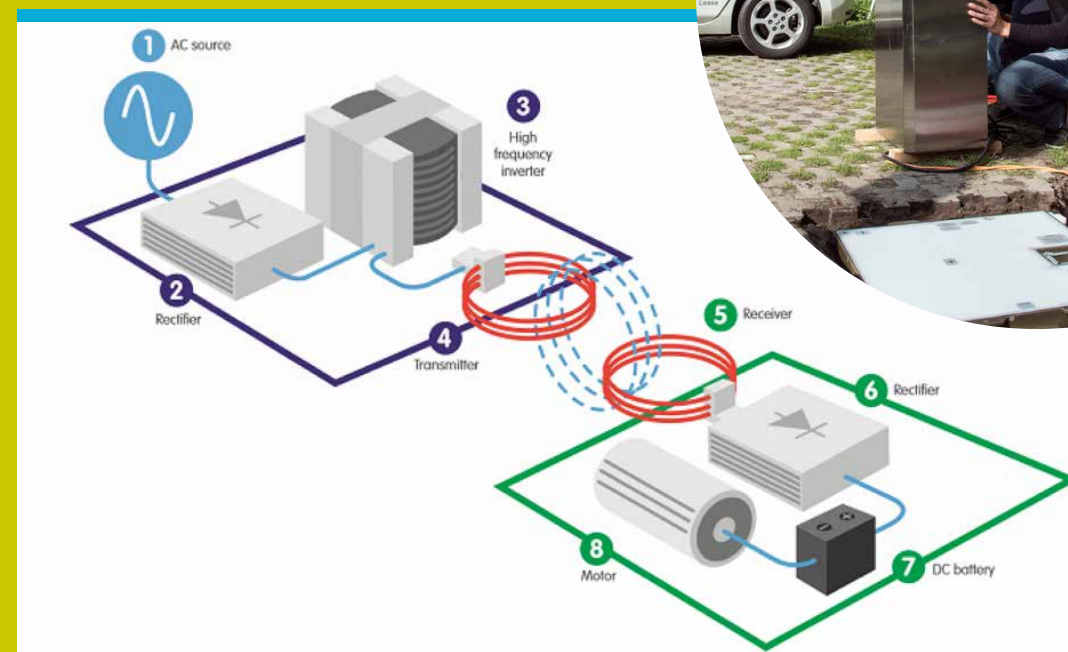


Figure 10
Wireless charging



Adjustable charging speeds

The Smart Charging ecosystem becomes even more complex if we take into account that the effective charging speed is influenced by other energy users and providers. If many devices simultaneously require power at the location, for example cars, heat pumps, elevators, and data centres, or, alternately, if power is fed into the grid from solar panels, EV charging speed can be adjusted to ensure an optimal balance. Currently, a number of variants of Smart Charging are available that can, dependent on user-needs, determine effective power distribution.

If **many cars** are simultaneously connected to a charging station or centre, the maximum charging speed is adjusted downwards. This simple form of Smart Charging is called 'local load balancing'. There are many other options.

At home, for example, information from the smart meter can be used to adjust the car charging speed to household consumption: the speed can be optimised to match electricity consumption in and around the house. Cars can charge less or not at all at times of peak demand; they can even supply extra power (V2H Vehicle to Home). This shows that a lot is possible even within the existing grid connection.

This is also true for an **office location**, where the charging needs and grid connection can be determined on the basis of the annual peak power consumption.

Photo
Fastned fast charging

Source: Fastned



Smart Charging can therefore be used to optimize the total energy consumption at the location and to minimize the size (and therefore the costs) of the grid connection. Most employees with an electric car will be in their office for a large part of the day, therefore the time when their EV is charged becomes less important. The office building's energy management system can optimize charging. On sunny days, for example, the afternoon would be optimal for EV charging, using the power from solar panels, and in poor weather conditions, the first cars could be charged in the morning.

The situation is somewhat different when we look at fast chargers. A location which only has fast chargers, for example along motorways, is expected to have a high peak consumption. If all the charging points are occupied, demand for electricity is at a maximum, while consumption plunges to zero if no cars need charging. In other words, power consumption can fluctuate enormously. Depending on the demand or throughput speed at the charging points, fast charging station operators could install a large battery, partly powered by solar panels. This can then be used to accommodate the peaks which occur when many of the charging points are in use. At quieter moments, the battery can recharge. However, this solution only becomes attractive if the investment in these large batteries is lower than the additional cost of a more powerful grid connection.




BATTERY
ON WHEELS

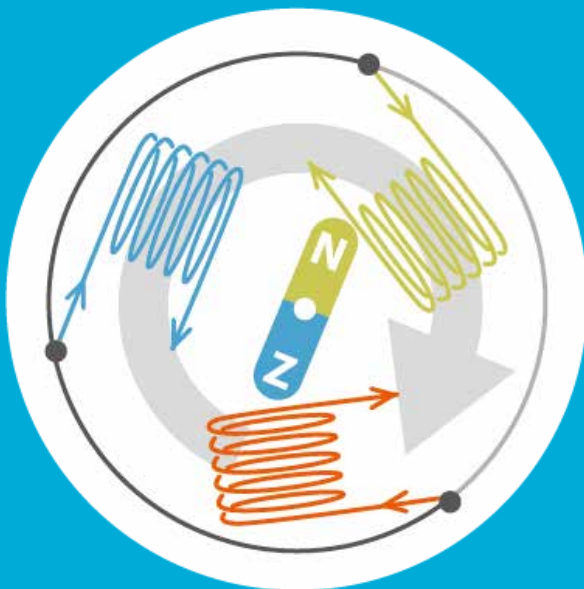


Maximum charging speeds

The difference between 1 and 3-phase charging

When generating electricity, a magnet rotates between three separate magnetic fields, with three distinct wave cycles (phases). Each phase is connected to a single power wire.

Most household appliances only require a 1 phase connection. However, in some cases, appliances that use a lot of electricity such as electric hobs or ovens are connected to 2 or even 3 phases. In the metre cupboard, as a safety precaution, each phase is fitted with a fuse to protect against short circuits or overloads.



Electric cars

Many of the first generation EVs only charge using 1 phase, with a maximum current limited to 16A, corresponding to a charging speed of 3.7kW ($16A \times 230V \times 1 \text{ phase}$). This applies to almost all plug-in hybrid electric cars.

Car manufacturers have since developed a number of models that charge at a maximum current of 32A with a charging speed of 7.4kW ($32A \times 230V \times 1 \text{ phase}$). There are even some models where 3 phase charging is possible.

We expect the vast majority of new car models to be fitted with a 3-phase charger with a current of (at least) 16A per phase and a charging speed of 11kW ($16A \times 230V \times 3 \text{ phases}$). These models can also charge if only 1 phase is available, only this will then be slower. However, if less than 6A is available, the car will stop charging.

Charging points

Street-side charging points almost always have 3 phases. As a charging station never 'knows' what kind of car will be connected, it always reserves the maximum current for all 3 phases. If an EV indicates that it can only charge on 1 phase, most of the current charging points reserve all 3 phases for this car. Moreover, at the request of the grid operator, the power wires are usually 'twisted' across the 2 sockets, so that if two 1-phase cars are being charged, 2 different power wires (phases) are used. This helps maintain an even distribution across the 3 phases.

At home users can choose between 1 and 3 phase chargers. This usually depends on their EV model. Home chargers are always connected to a separate group in the metre cupboard. In the case of a 3-phase home charger, the mains connection must also have 3 phases; in some cases the grid has to be reinforced from a 1 to 3-phase connection.

Location determines Smart Charging options

The charging station's location is an important determinant of a user's Smart Charging options. If you charge at home or at work, your EV will often be parked at the charging station for a long time. However, if you're only there for a short time and/or have to charge en route, you'll want to charge your EV as quickly as possible.

Charging speeds offered by charging station, per location

Home	Office	Visit	Travel	Charged km per hour	Power (kW)	AC/DC
Short stay	Extended stay	Short stay		>7 en < 17	1,4 - 3,7	AC 1X6A/1X16A
> 8 hour	park	park		>17 en < 55	7,4-11	AC 1x32A/3x16
				110	22	3x32A
				250	50	DC
				750	150	DC
				1750	350	DC
			Stop & Go			
			< 1/2 hour			

The table shows the typical charging speeds offered at charging points, dependent on location. At home, the charging point is either a wall-mounted box or a street-side charging station. The charging speed starts with a power comparable to a single outlet (1.4 kW) and can reach the power of an entire house (11 kW). This is shown in the table in green. Some street-side charging points can be even faster (22kW), these are shown in blue. Fast chargers have even higher capacities; these are coloured red, indicating that this charging speed is not usual for that location.

Fast charging stations located on motorways serve this purpose. Some of the charging stations will be shared by different groups of users. A city centre charging station will commonly be used by office staff during the day, by visitors in the afternoon or evening, and by residents in the evening and at night. There are also a number of specific user groups such as taxis, shared cars or inner-city logistics.

This variety of users influences the options for Smart Charging. At locations where the parking time is longer than the time required to top up the car, there are a number of logical options for Smart Charging. The most important possibilities for Smart Charging are home-charging and/or office-charging, or when the car is parked for a longer period, for example at a theme park.



Using data for customisation

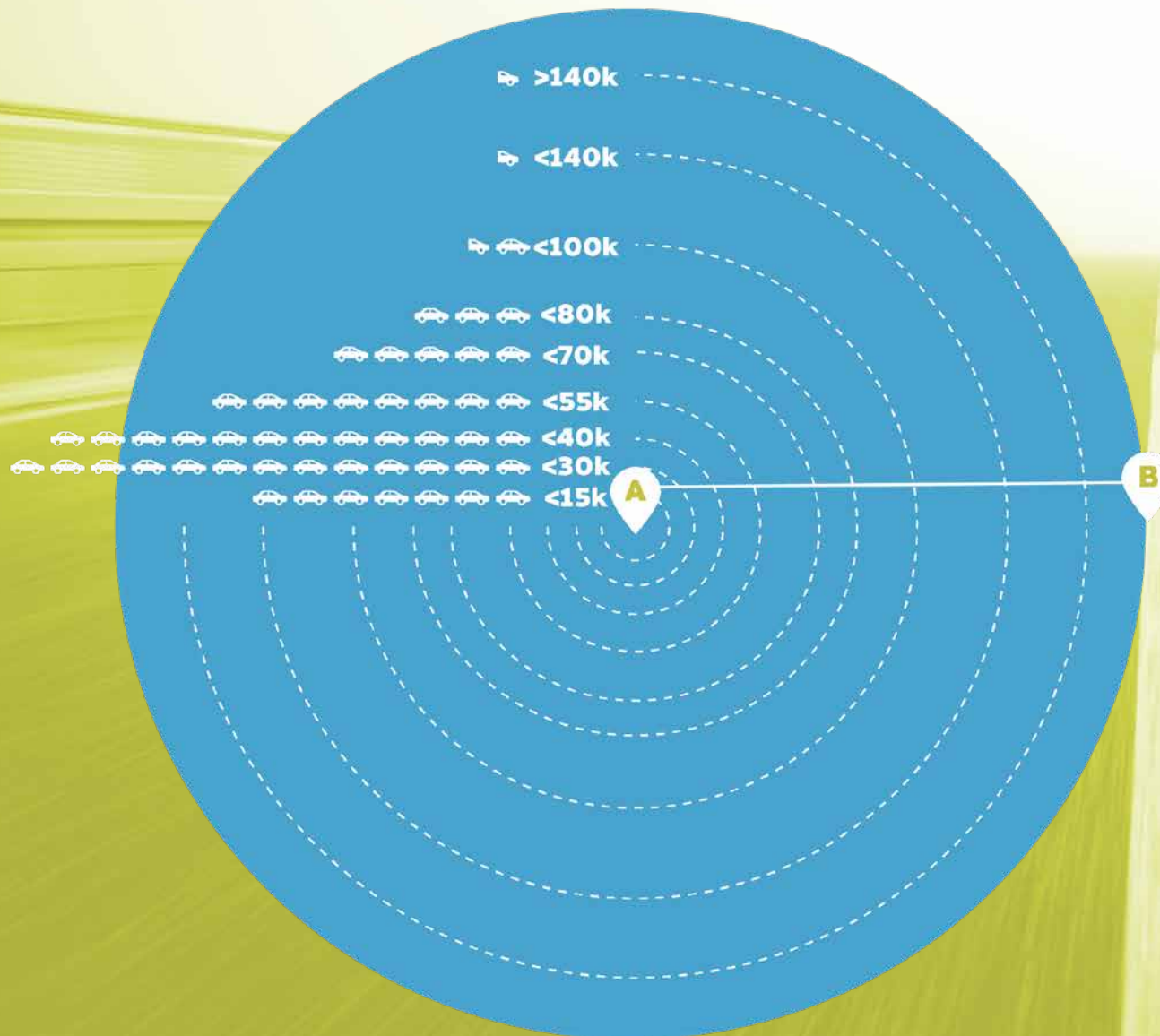
A control signal is normally all that is needed for simple forms of Smart Charging. For example, the charging station can then transmit more or less power at specific times within the available bandwidth.

However, for a more optimal and complex use of Smart Charging, you need data. The more information available, the better the system can be customised to your needs. The charging station can then base charging decisions on information about how full the car's battery is, the time the driver has to leave, or whether nearby solar panels can provide extra power, and of course, much more. We have listed some examples of the different data types:

Driver	Parking time (departure time - arrival time) Desired kWh (minimum and optional) Price preferences price Energy mix - solar / wind Choice of Electric Mobility Service Provider
Car	Supported charging speeds Battery size (kWh) How full is the battery? (state of charge)
Charging station (location)	Number of charging points Supported charging speeds
Local electricity grid	Contracted maximum capacity grid connection
Related local energy system	Presence of solar panels, static battery, home, office, etc. Consumption or generation of related energy systems



Just pause for a moment ...



It's not common knowledge, but on average, a car drives no more than 35 kilometres a day; in fact, very few exceed 100 kilometres. Many more only drive less than 15 kilometres daily.

Photo
Road surface

Source: Pixabay

Playing with time and power

If Smart Charging is not applied, the maximum charging speed is determined right at the start of the charging session as a result the weakest of the three components: car, charging station or grid connection. The charging profile then is: transfer as much energy as possible until the car is full. With Smart Charging, you can 'play' with both time and power resulting in many different profiles and strategies.

First, let's look at the control options for an individual charging session. We assume a standard speed of 12 Ampere per phase. This is what a standard public charging station with two charging points provides if two cars charge simultaneously. The following control options are then possible:

	Ampere's per phase (A)	3 phase power (kW)	Km per hour charged
EN			
Standard	12	8,3	40
Accelerated	16 - 32	11 - 22	55 tot 110
Delayed	>6 en <12	4,1 - 8,2	20 tot 40
Paused	0	0	0
V2G	>6 en <16	4,1 - 11	-20 tot -55

Three main control options form the essence of a Smart Charging session: charging can be speeded up, slowed down, or paused. However, if bidirectional charging (V2G) is available, this adds a fourth option: energy supply. From an electrical engineering perspective, discharging is exactly the same as charging, only in the opposite direction. In this case the direction is opposite to charging - energy leaves the battery – so the number of kilometres charged is negative.



The options to manage charging are fairly obvious: charging can be faster, slower or even paused.

Charging in the future: new habits!

How we charge an electric car differs substantially from how we fill up our cars with fuel. Charging leads to different behaviours and habits. Although some electric car drivers use the fast chargers located along our motorways, which to some extent is comparable to refuelling, the majority of drivers charge their cars at their destination. This is usually at home, on private property or in the neighbourhood on the street, but it can also be at work or during a visit. Filling a tank completely usually only takes a few minutes, however, with an electric car you use the time that the car is parked to 'fill it up', with new energy. As a car usually spends up to 95 percent of the time parked, there is more than enough time to charge it at the most ideal moment.

The charging behaviour we currently see gives us insights into future developments. However, today's users

are a specific group that usually consist of lease and business drivers. This group is not representative of future users.

An average car clocks up around 13,000 km per year in the Netherlands, with privately owned vehicles traveling less at around 11,600 km, and commercial vehicles at around 23,000 km. We expect the large group of vehicles not used for commuting to show a different charging behaviour than the current 'frequent' driver. What the charging behaviour of future users will look like exactly is highly dependent on variables such as the cost of charging, the development of available charging infrastructure and capacities, and the acceptance or adoption of Smart Charging.

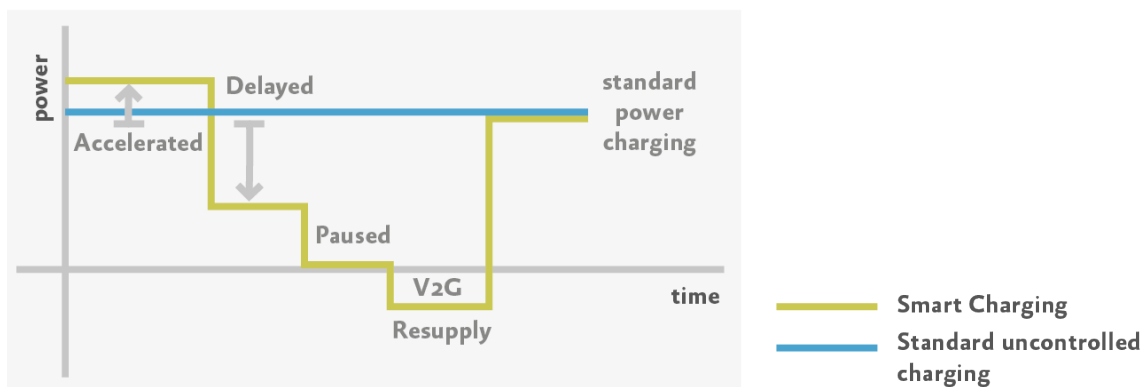
A few (rounded) numbers as an illustration:

- 8 million passenger cars.
- An average of 13,000 km / year.
- Energy consumption is 0.2 kWh / km, so 2,600 kWh / year.
- Average battery capacity is 50 kWh.
- Assuming 35kWh per charge.
- Each car is then charged approximately 75 times a year.
- Or, 1.4 times a week.
- Car-charging can easily be spread over all seven days.



The Smart Charging control options lead to a charging profile or strategy. An example: instead of standard, undirected charging (blue straight line), the car charges more at a certain time and less at other times.

Figure 11
Example of Smart Charging
versus standard charging



In the graph above, the charging profile indicates the charging speed (green line) and the area under the charging profile represents the total amount of charged energy (kWh).

Different Smart Charging techniques

The control options for an individual charging session are not deployed randomly; they are based on conscious choices and strategies. An individual session profile is often partly the result of an optimisation over several ongoing charging sessions. Choices are made that are not only beneficial for the individual session but also for the group. Optimising a group of charging sessions is similar to what the energy world terms 'demand-side management' (DSM) or 'demand-side response' (DSR).

DSM is used to mitigate strong peaks and troughs in a consumption pattern and to balance the energy profile. How this is achieved depends to a large extent on the basic profile; this is mainly determined by usage. For example, the basic profile of a house is very different from that of an office, a hotel, a store or a location with fast chargers.



Cryptocurrency, blockchain and Smart Charging

Most people are aware of terms like cryptocurrency (with Bitcoin as the best-known example), blockchain, and perhaps even distributed ledger technology (DLT), however we won't go into details of the underlying technology here. Currently, many people are experimenting to see where and how these promising techniques can be applied in practice. One of those applications is in the Smart Charging ecosystem.

In the current charging infrastructure, we pay with a charging card and in the future, this will be replaced with certificates (public key infrastructure).

One of the pilot projects incorporated blockchain technology in a charging station. IOTA (a form of DLT) was chosen: there are no extra transaction costs and no (data) mining is involved.

In this situation, when charging an EV using a cable, a connection is created between the car and the charging station. The car indicates how much energy it wants to charge and the charging station tells the car how much this will cost before placing the transaction on the IOTA network. The charging station waits until the network approves the transaction costs, then the car can start charging.

All transactions in a Smart Charging ecosystem could use the IOTA network. For example, your solar panels could supply power to the neighbours' electric cars, and the grid operator could possibly reward clients for using less or more energy at specific times of the day.

These transactions can be made by anyone and are not bound by national borders. As the IOTA network stores everything, a complete audit trail of supplied power and the associated costs is available: everything is fully automated.



Depending on the basic profile, a number of Smart Charging techniques can be applied. There are a number of options to optimise Smart Charging sessions:

Figure 12
Simplified representation of
Smart Charging techniques



- **Valley filling:** more or faster charging at periods of low energy demand.
- **Stimulation:** faster charging when more sustainable (or cheap) electricity is available.
- **Load shifting:** slower charging at times when peak loads are imminent; EVs then charge faster at other times.
- **Energy conservation:** at the time of charging, the speed is reduced to less than the technical maximum for the entire charging period.
- **Peak clipping /peak shaving:** less rapid charging at times when there is a risk of peak loads.
- **Power production:** resupply of energy from the EV.

The Eindhoven flexmarket test

As part of the European Interflex project, researchers at Strijp S in Eindhoven are investigating a future energy market by creating a local, flexible market. If the grid operator requires flexibility because (in the test) there's a threat of grid overload, flexibility can be purchased on the market. This could then be provided by a neighbourhood battery or from EV Smart Charging. Researchers are

investigating how this type of flexible market could work, what it involves, and how effective it may be.

The project's aim is to effectively monitor and manage the entire local energy system. Communication protocols are being further developed for this.

**Flexibility is auctioned
in the Interflex
project.**

Photo
Interflex

Source: Interflex



In these charging strategy visualisations, we disregard local electricity generation options such as solar panels, battery storage or an EV with a feed-in function. The presence of local generation has a number of consequences and creates additional possibilities. In the case of solar panels, the basic grid profile at the location in question will be the first to change, as solar generation cannot be controlled. If there is no energy consumption, electricity is supplied to the grid. The maximum energy supply to the grid is limited by the size of its connection; this may be a physical or legal capacity limit – e.g. the customer has agreed a certain maximum with the grid manager. Curtailment occurs when the generation capacity cannot be fully utilized because the grid connection has insufficient (contracted) capacity, and the power peak of the production must therefore be reduced. The alternative to limiting generation is to stimulate local consumption; this can be done by charging EVs or a fixed battery. It is also possible to opt for a strategy to charge batteries when sufficient free grid capacity is available, and to supply it back when demand is high; thereby preventing peaks in demand.

Taking this one step further: the car can function as an energy supplier

When electricity is added to the grid, the situation becomes far more complex as well as more interesting. In this case, both speed and time can vary and be adapted to a number of strategies. For example, the EV can support the grid at times of high demand, or it can store locally generated electricity from solar panels and supply it to a home in the evening. The car can even become a power trader, by demanding energy at times with low prices, and resupplying it when prices are higher. In other words, by using the EV as a buffer, Smart Charging strategies can be implemented even more effectively.

Conclusion

The technical layer therefore determines whether it is possible to charge smartly, which routes are possible, how data can be customised and delivered, and within which bandwidth. This then provides us with initial insights as to how charging profiles and strategies can be used with Smart Charging.





3.2 The communication layer

Crucial to Smart Charging is the ability of various devices to communicate with each other. We look at the different routes that can be used for this, but also at the language which devices use to safely 'talk' to each other.



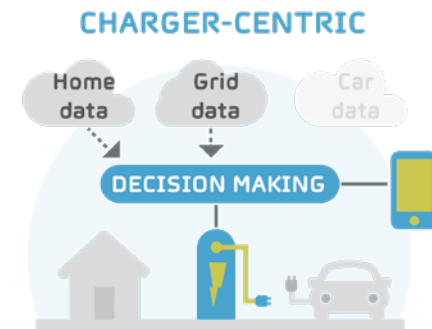
Different routes

There are many possible routes of communication, but in all cases, the Smart Charging signal must be communicated to the car or the charging station.

There are currently three main routes to activating Smart Charging:

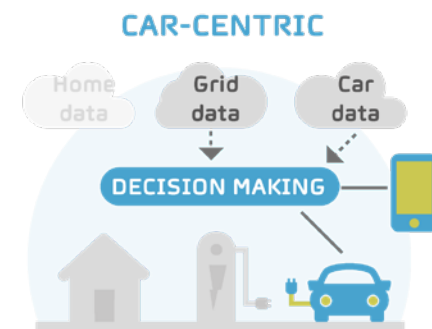
1. Smart Charging via charging infrastructure (Charger-centric)

In this example, the grid operator gives a signal that runs via the back office system to the Smart Charging station, which in turn permits the car to charge faster or slower. Many Smart Charging tests currently being conducted in the Netherlands on public charging points are managed in this way, for example the frameworks for the FlexPower and INVADe projects. The signals in the example are provided by the grid operator, but they could also be from other stakeholders, like the energy supplier.



2. Smart Charging via car (Car-centric)

This route that runs via the car is also termed Telematics; the combination of telecommunications and data available in modern cars. The car manufacturer thus receives real-time information about the car and can send information to the car. This system can also be used to generate a Smart Charging control signal which could be provided by a party needing flexibility - the regional grid operator, the national grid, or another party - or through an intermediary, a so-called aggregator. This signal runs via the car manufacturer to the EV which then starts charging faster or slower. Whereas the charging infrastructure route requires fixed charging points, car-centric charging involves moving cars where control signals will have to be sent, for example, on the basis of GPS coordinates, which the car manufacturer then translates to those cars charging in that specific area.



Why open standards are so important

Open standards in IT communication between different devices like charging station, car or back-office systems need to be transparent, user-friendly, and offer consumers freedom of choice.

Open standards lead to better solutions because many parties work together on an equal basis, leading to cheaper solutions. These better, cheaper and widely available solutions will accelerate the roll-out of the Dutch charging infrastructure and ensure that Smart Charging is a success. Smart Charging requires communication for transmitting control signals, so it is essential that a universal 'language' is used to enable control of each charging station via any back office system, regardless of brand (OCPP). At the same time, every EV has to be able to talk to every station (ISO 15118) and possibly even to the solar panels on your roof, independent of brand: there must be no lock-ins tying users to a specific brand.

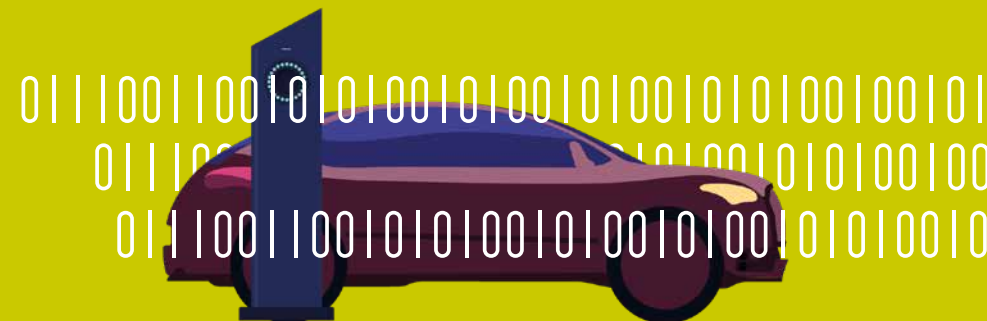
Finally, open protocols strengthen the export position of the Dutch EV-sector: as an open standards leader, the Netherlands has access to other markets.

More benefits

- An open infrastructure is good for the Dutch e-driver. The OCHP and OCPI open protocols give the Dutch e-driver easy access to more charging points, both at home and abroad.
- Innovation and competition is encouraged. This translates into better services, lower prices and more new services such as Smart Charging, Plug & Charge, Car-sharing, et cetera.
- Open protocols help to accelerate the introduction of e-driving in the Netherlands.
- Parties that invest in charging infrastructures (companies, municipalities, provinces) have the freedom of provider-choice. They can choose the best price / quality ratio, add new providers to their existing infrastructure, and develop new services.
- There is a large number of e-driving stakeholders: the consumer, hardware makers, Electric Mobility Service Providers, energy companies, municipalities, car manufacturers. By

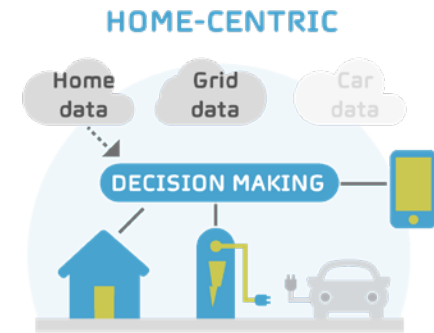
developing a shared protocol, each stakeholder's interests are assured, and joint solutions can be introduced faster.

- Knowledge-sharing between a range of parties and countries leads to incremental gain: through open cooperation, new ideas and best practices spread faster. Electric transport is a global market where international cooperation is a 'must'.
- Open protocols are good for the export position of the Dutch EV industry as products developed here can be used in other countries without any modification.
- Open protocols for the charging infrastructure can be reused, enabling interaction with other devices such as heat pumps and solar panel inverters.



3. Smart Charging via Energy Management System

The Smart Charging signal can also be sent via an Energy Management System (EMS). Increasing numbers of (office) buildings and homes now manage their own energy consumption. In addition to providing information about the building's consumption, EMSs also protect the connection against overloading in the event of excessive consumption. It would also be applicable to charging an EV if the charging station is connected to the building. In this route, the grid operator or another party determines whether the EMS can charge the car faster or slower. Currently, many protocols have been developed specifically for Energy Management Systems; we expect that these protocols will become increasingly compatible with EV standard protocols.



Open standards and protocols

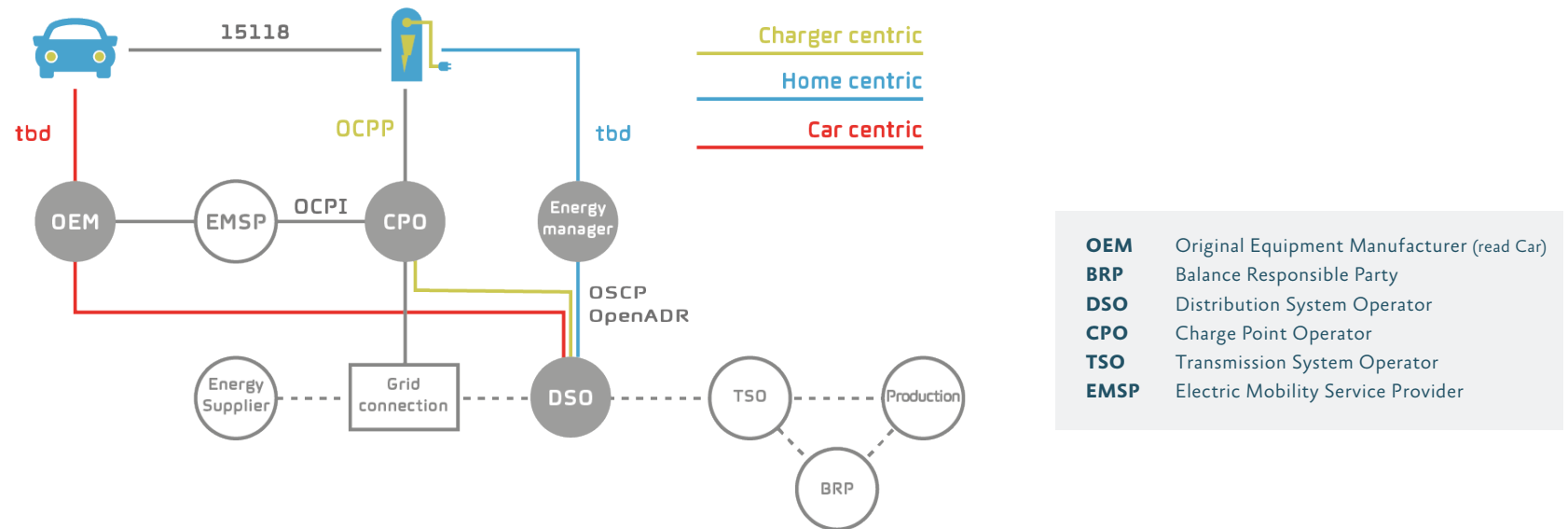
Standards and protocols play an important role in all these routes; these are the languages that determine how one device communicates with the other. These are preferably 'open', developed so that they can be used by the entire industry and stakeholders. The Netherlands is at the forefront of the development of open communication standards for charging electric cars, and the international community is following. In recent years, together with many national and international stakeholders, a number of open communication protocols have been developed, namely **OCPP**, **OSCP** and **OCPI**. Below, we define these acronyms in relation to Smart Charging. For the sake of clarity, we have not included roaming protocols.

OCPP (Open Charge Point Protocol) is an open protocol for communication between the charging station and the central backend system of the charging point operator. It controls the entire charging transaction. OCPP was initiated by ElaadNL in the Netherlands and developed further in recent years by a broad international group of EV-industry stakeholders. OCPP is the de facto international standard and is currently applied in more than 100 countries worldwide. OCPP is now managed by the Open Charge Alliance, an international industry alliance with 136 members from dozens of countries on five continents. OCPP makes it possible to pass on Smart Charging signals from the central backend system to the charging station.



OSCP (Open Smart Charging Protocol) is an open communication protocol between the charging station management system and the grid operator (regional grid or national grid operator). It communicates the capacity limits within which charging can occur without causing grid overload. This protocol also originated in the Netherlands, however it is not often used in practice.

Figure 13
Communication, protocols
and standards



Open ADR (Open Automated Demand Response) is an open standard for exchanging 'Demand Response' signals, or signals related to price or charge control. This enables Smart Charging signals to be sent between parties, for example from the grid operator (DSO) to a charge point operator (CPO). The communication is based on IP communication networks such as the internet. This protocol is widely supported. In the United States it is commonly used.

OCPI stands for Open Charge Point Interface between a CPO and a Third Party, usually being a charging service provider (Electric Mobility Service Provider = EMSP), but this could also be another party such as an energy supplier or aggregator. OCPI originally only worked peer-to-peer, but now also supports Roaming Platforms (including e-clearing.net) via a hub-to-peer connection. OCPI is a Dutch initiative with wide international support. The protocol provides real-time information about the charging station such as location, availability, prices, billing, as well as ensuring

Project FCR: maintaining balance using electric cars

In 2017, a pilot project called Frequency Containment Reserve (FCR) was started to investigate whether electric vehicles could support Tennet's primary reserve market. The aim was to see whether the charge capacity could be adjusted within 15 seconds and that an update to the actual capacity could be registered every 4 seconds. This is necessary to manage changes to the grid frequency. Results showed that approximately 95% of the charge profiles reach the charging station within 2 seconds. The project team concluded that it is possible to respond quickly enough in almost all cases, with the exception of offline charging points. The researchers reached a number of interesting findings:

- The standard speed of charging cars is set at the maximum, which means that they can only demand less power and not more. This can be solved by setting a lower default charging level.
- At night, the collective charge capacity drops practically to zero as all cars are charged. At that time, no power is available to manage the balance.
- In a year, the collective charge capacity is too low for about 25% of the time.

If Smart Charging were to be used optimally, this would change (see figure below) and the desired minimum power would always be available.

- The so-called PWM signal used to communicate the maximum charging current to the vehicle from the charging point can become distorted in a (long) charging cable. The vehicle will therefore always interpret the control signal as being lower than that sent by the charging point.
- Although the so-called 'mode-3' power control works continuously in principle, not every power level can be reached. Depending on the design of the vehicle's charging electronics, the vehicle can probably only make a number of intermediate steps between the minimum current of 6 amps and the maximum current of (usually) 16 amps. This differs per model.
- In addition, for some car models, a higher minimum current rating can apply, e.g. 12A.
- Another finding is that vehicles may always charge slower than indicated by the control signal. This occurs naturally when the car's battery is almost fully charged, but it can also happen at any time during the charging session.
- And finally it's important that the charging point clock is correctly synchronized with the charging provider's charging profiles. Should they differ, the charging behaviour can be different.

Figure 14

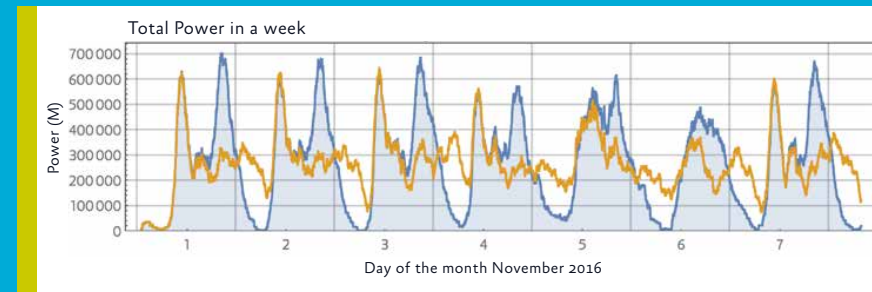
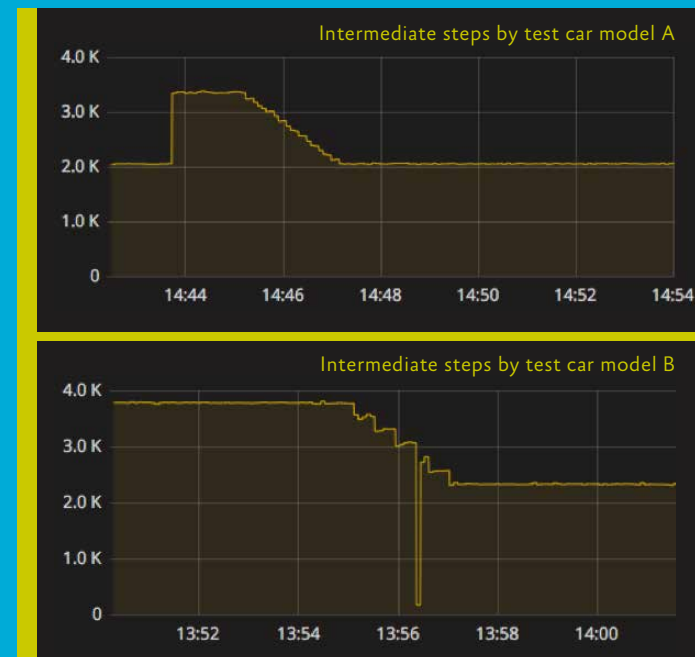


Figure 15



bilateral roaming. The Smart Charging functionality has been included in the most recent version of the protocol (v2.2).

ISO 15118 is an international protocol for communication between car and charging station. In addition to its extra focus on security, an added value is that it makes it possible to communicate the user's departure time and the car's energy requirement (how full the battery is) from the car to the charging station. This then makes it possible to charge smarter, more efficiently, and better match the driver's wishes. In addition, it allows the Smart Charging control signal to be communicated between the car and the charging station.

Cybersecurity

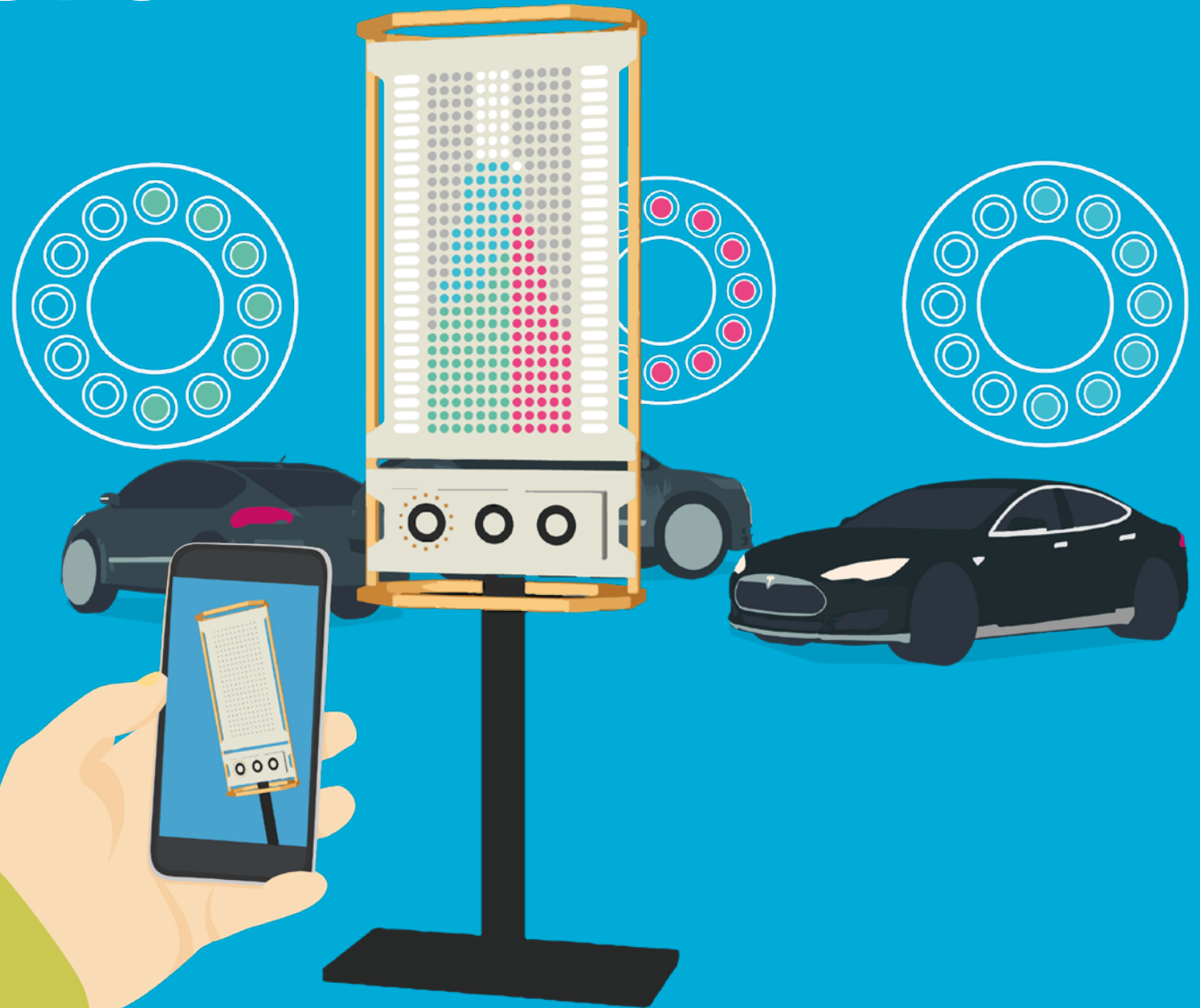
An extremely important aspect in all cases of communication is cybersecurity. The Smart Charging signal must be sent safely, without anyone being able to see or adjust it. Both the grid and our mobility are crucial in modern society; they even form part of the critical infrastructure. Thus they have to be well-protected. As more electric cars come into circulation and charging/discharging becomes an increasingly important part of the energy system, there is a growing need for cybersecurity. By linking our mobility to our energy supply and vice versa, it is essential that we ensure that the charging station network is stable and secure (non-invasive).



The transparent charging station project

As there are increasing numbers of EVs, and not all of them will be fully charged at the same time, gaining insights into charging behaviour are increasingly relevant. Which choices were made by Smart Charging algorithms and what were the consequences?

This is the idea behind the Transparent Charging Station project. A prototype was introduced in 2017 and won a 2018 Dutch Design Award in the category 'Product'. The project makes visible what is currently invisible, and will be integrated into the FlexPower project in Amsterdam. In this project, electric shared-cars are given priority; they are charged faster during off-peak hours, optimizing sun and wind power use. Together with the municipality, we are working on the best ways to provide transparency.



Charging stations should only be controlled by recognised legal persons and organisations. Three points are important:

- Secure communication from and to the charging station through the use of, amongst others, secure protocols, servers, and infrastructure.
- Physical charging station security by, amongst others, using sensors that detect unauthorized use of a charging station, secure encryption key storage, and secure software development processes.
- A secure (mobile) network and server infrastructure.

In order to support governments that tender for charging stations, ENCS (European Network for Cyber Security) and ElaadNL have drawn up requirements for the field of cybersecurity.

Conclusion

The communication layer describes the routes and languages via which the various devices communicate with each other. Much of this communication runs through open standards, emphasizing the need for excellent cybersecurity.



Large-scale testing of Smart Charging algorithms

As part of EU Horizon2020 program INVADE, Smart Charging was performed on over 1,000 public charging points for a full year. The charging points were virtually relocated to two neighbourhoods in the Netherlands to simulate the near future scenario in which all cars are electric. Charging profiles were formed as the result of grid capacity limits from the neighbourhoods and commercial decisions added by the commercial optimiser. These requirements were matched in a data platform created specially for INVADE, after which the resulting profile was sent back to all chargers. Each change in available grid capacity or the number of active sessions resulted in recalculation of

the charging profiles. Although more than half of the sessions received significantly lower charging speeds, no differences in total charged energy were measured between sessions, indicating enough flexibility in the connection time. The project also showed that extra measures are likely to be needed during peak times in winter, where researchers found that the available grid capacity mismatched the lower boundary precondition used in this project during early evening.

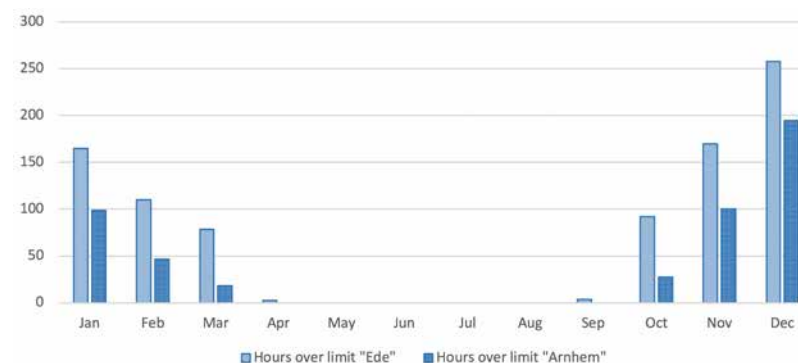
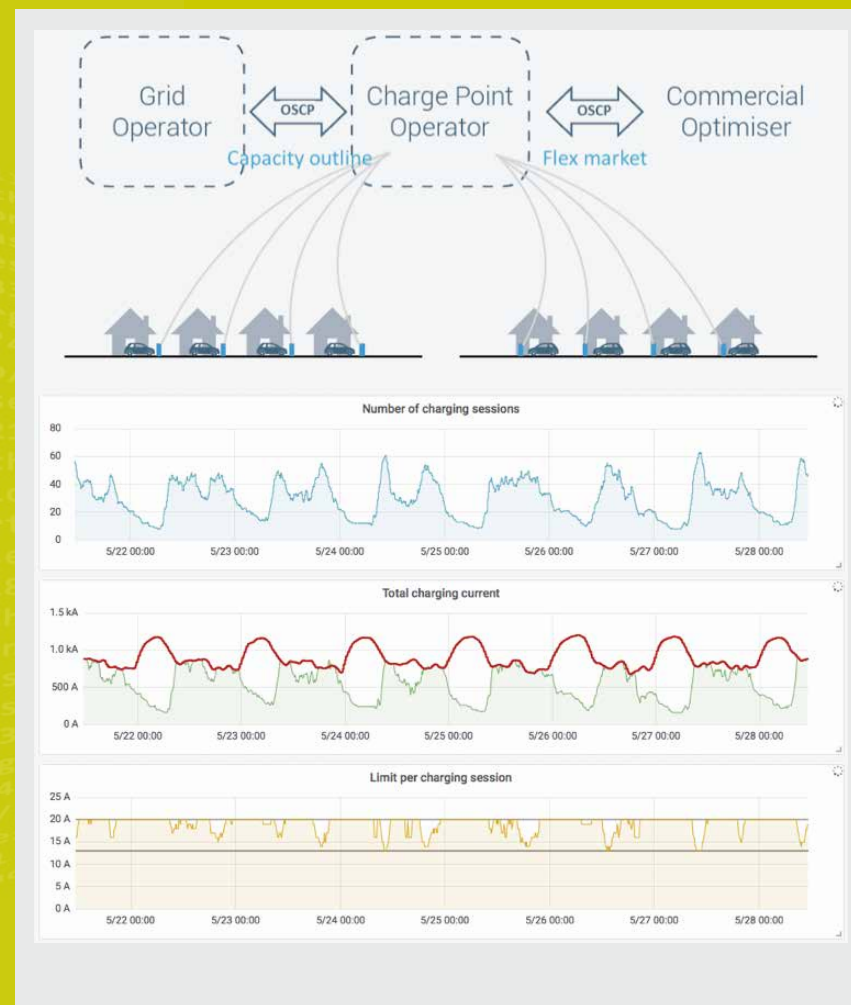


Photo
Nynke Arends



3.3 Organisational layer

The third is the organisational layer. It describes the interests and strategies of the stakeholders involved in the Smart Charging ecosystem. Ultimately, these translate into wishes for a specific Smart Charging profile. One of the major challenges we face is that they do not all lead to the same desires.

Who wants to charge smartly and why?

To start with, let's see which stakeholders are involved, and what their stake is. These are quite diverse: consumers (e-drivers), car manufacturers, battery producers, charging station operators, charging station producers, service providers, aggregators, energy suppliers, (sustainable) energy producers, but also municipalities, provinces and the central government. They include national grid operator Tennet and the regional grid operators (medium and low voltage grid). There are probably others which we have forgotten! What are their interests and why would they want to charge smartly?

The consumer, preconditions and preferences

The interests of e-drivers naturally play a crucial role in Smart Charging; after all, it's the consumers who have to drive and charge their electric car. Their car is primarily a means of transport to get them from A to B without any problems. Their needs are paramount when it comes to Smart Charging. They need a range of options ranging from the opt-out 'charge me now' for urgent charging needs, to a (self-determined) lower action-radius limit for 'Vehicle to Grid', with for example, a no discharge option if only 30 kilometres is left in the battery. In addition to being able to determine use preconditions, consumers' preferences are also important. Will drivers opt for charging as economically as possible or as sustainably as possible, which in practice may lead to the same charging profile? Will consumers manage their own choices, or will they let their smart home energy management system or app do this as much as possible behind the scenes? In other words, it's important for e-drivers



Using EVs to store solar energy

Photo
We drive Solar

In the Utrecht neighbourhood of Lombok, the electric car is increasingly becoming part of a sustainable energy system. The idea: solar panels on public buildings, for example schools, provide electricity to power electric shared cars at times when there is a surplus. In turn, the cars can supply electricity to the grid at peak demand times.

Together with Renault, a number of Dutch partners developed charging points and cars that can both charge and discharge. Special to his project is that DC chargers (fast chargers) are not required; any public charging station location anywhere on the street (working on AC) is potentially suitable. Fast chargers are much more expensive and larger and therefore less suitable for large-scale rollout. Another special feature is that the communication between the car and the station takes place through specially developed open protocols that allow every charging station and car manufacturer to work via the same system. This makes a global rollout possible!



His Royal Highness King Willem Alexander, together with Jérôme Pannaud (r), director of Renault Benelux and Robin Berg (l), director of We Drive Solar, opened the first European V2G project in Utrecht on 21 March 2019.

to be able to state their own preconditions and preferences, and that these are used when interpreting Smart Charging needs. All this should not lead to consumers being faced with extra demands on their time and/or effort.

However, a car remains unused most of the time, and is usually plugged into a charging station, so there are plenty of opportunities for Smart Charging that benefit the consumer. Smart Charging can mean: that you charge more cheaply (at those times when the electricity price is lowest), that you charge more sustainably (making optimum use of your own solar panels or the local wind farm) and in the case of bidirectional charging (V2G), store electricity from solar panels for later use. In some Smart Charging projects, motorists can also charge faster at certain times (FlexPower project). Thanks to Smart Charging, more charging points can be added to the same grid connection. For example, a car park can be fitted with more charging points without the need for a heavier and more expensive grid connection; this also applies to charging bays. Moreover, there are a number of indirect benefits. For example, a massive application of Smart Charging can prevent the need to reinforce power grids, thereby reducing the need for additional power plants. Avoiding these costs will result in less high energy bills.

Companies: making money with Smart Charging

A range of businesses are involved in the Smart Charging ecosystem; they are competing to gain a position on the currently unregulated market for charging infrastructure and charging services. All have developed propositions that respond to customer needs, while providing a healthy revenue stream. The customer agreements and the business model determine who, in the end, will control the Smart Charging chain. The various (smart) charging customer propositions almost always include a combination of mobility, electricity, and digitization. And the positioning of the customer propositions are usually centred around the vehicle, the charging infrastructure, or location. Below, we have included the best-known Smart Charging stakeholders. It should be noted that these companies use a number of suppliers and sub-contractors, including battery manufacturers, installation businesses, IT companies, car sharing providers, consultants, and many more.





Photo
Jacco van der
Kuilen

Car manufacturers

As car manufacturers continue to work on reducing car emissions, they will increasingly move to manufacturing electric cars. This increase in numbers of EVs in turn has many consequences. Amongst others, that all these new EVs will have to be charged, sustainably and problem-free. We have already noted that Smart Charging is an essential element of this future picture. A number of manufacturers, including Renault and Nissan, have also embraced the idea of bidirectional charging. This makes your car, just like your solar panels, part of a sustainable home or neighbourhood network.

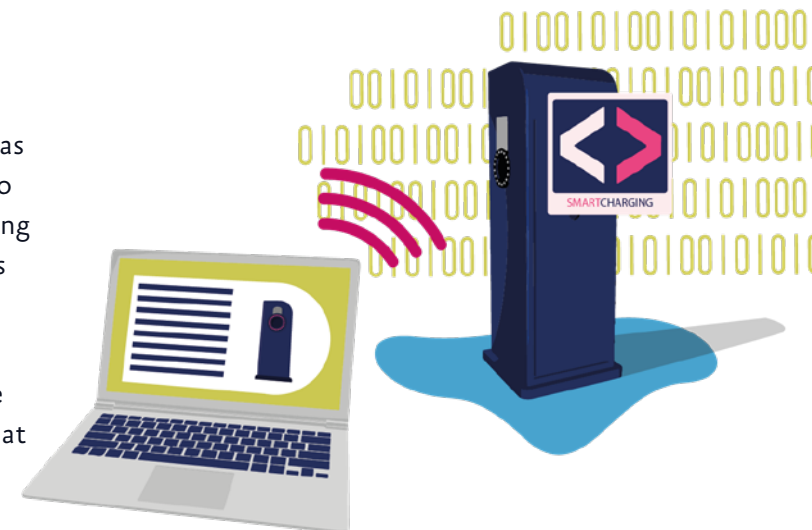
Another important effect is that electric cars require much less maintenance, so this will lead to other business models. For example, the major car brands will provide other innovative services, such as fast charging points and supplying power for car charging. Perhaps Volkswagen will purchase electricity on a large-scale so that you can charge your VW cheaply. And perhaps we're increasingly moving from being car owners to forms of rental construction; mobility as a service. Another important strategic aspect is the way in which the Smart Charging control signal is given. If this goes through the car, this reinforces the position of the car industry. Data availability also becomes crucial; with Smart Charging, you'll want to know how much power is stored in your battery (the state of charge), but who owns that information, and (how) is it shared? Consumer-groups need to initiate this discussion, but we currently see that the car manufacturers and associates will retain most of the power in determining who sees what.

Charge Point Operators, or CPOs

When Smart Charging is used more charging points can be connected to a grid connection or to your own transformer, so that more charge transactions are available without any loss of driver comfort. This is possible in the public arena, as well as in car parks or, for example, under an office building. CPOs will be able to meet consumers' mobility needs by providing a charging service, as well as offering flex services to flex-users. This will lead to an increased number of CPO business models.

Charge Point Manufacturers

Charge Point Manufacturers will, logically, play an important role. They will have to provide products that can cope with Smart Charging, with secure software that



Experience with the Jedlix Smart Charging app

Whoever wants to can already start Smart Charging. Some companies already provide Smart Charging services for companies and e-drivers. Startup Jedlix is the best known of these, providing a service driven by a smartphone app. After installing the app, Jedlix customers can charge smart at a select group of public charging points or at home. In practice this mainly means that charging occurs in the middle of the night when the wind

farms are fully running and there is little demand for electricity, thereby saving charging costs. The benefits are shared with app users.

Jedlix client charging behaviour was analysed over a period of months; a total of more than 10,000 anonymized charging sessions from nearly 140 different

e-drivers. The results were as expected: in general it appears that Smart Charging reduces charging in the morning and evening peaks. The total energy demand shifts to the night hours, with a 47% lower consumption at evening peak times (18:00 -21:00).

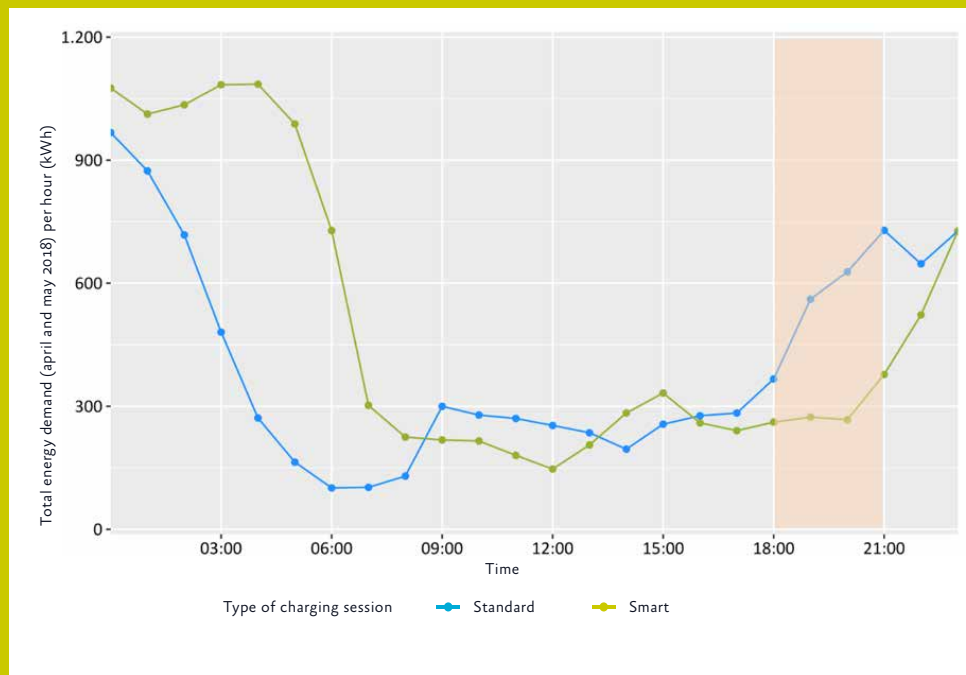


Photo
Jedlix app

Source: jedlix.com

communicates via the appropriate protocols and open standards. The Netherlands has a large charging station industry; we expect that with these innovations they can be international leaders in this field. By providing charging stations in semi-public spaces (at IKEA, the office or hotel) and private charging stations in people's homes, they often have direct contact with customers and can apply smart solutions if desired.

Electric Mobility Service Providers (EMSPs)

An EMSP or charging service provider is the party from which motorists purchase their charging subscription. This organisation can extend the charging service by facilitating Smart Charging. It is important that when offering this service, it must be clear to motorists which choices can be made when Smart Charging, and what the associated benefits are. The EMSP role can be provided by different types of companies: energy suppliers, charging point manufacturers, consumer organisations such as the ANWB (the Dutch AA), and more.

Aggregators

Other parties can start trading in the provision of a flexible electricity supply and demand. A new role is that of aggregator; an aggregator bundles the power demand from multiple EVs or charging points. They can make a proposition based on cost-effective, transparent and profitable management of the marketplace's flexible providers. Smart Charging of electric cars is an important source of flexibility. A charge point operator can also choose to take on the role of aggregator.

Energy suppliers

Energy suppliers can potentially make a profit from Smart Charging by supplying energy at times when electricity is cheap. As they are responsible for a continuous power supply, they can use Smart Charging to prevent any system imbalance-fines by matching demand to the previously submitted energy programme. As Smart Charging can be used to flexibly charge cars, energy suppliers have many options to play with, especially as car-numbers increase. Therefore, if there are unexpected changes to energy supply provision, Smart Charging can offer a solution.

Sustainable energy producers

Smart Charging benefits producers of sustainable (sun & wind) energy. If this is applied on a massive scale, the demand for electricity can, to a large extent, be adapted to the supply. In this way more sustainable electricity can be available to





Photo
Cable

Source: Alliander

the energy system without the need to disconnect sustainable electricity due to curtailment. This means that power demand can be managed at favourable times, improving the yield of generated electricity. In this way, Smart Charging guarantees optimal use of sustainably-generated energy

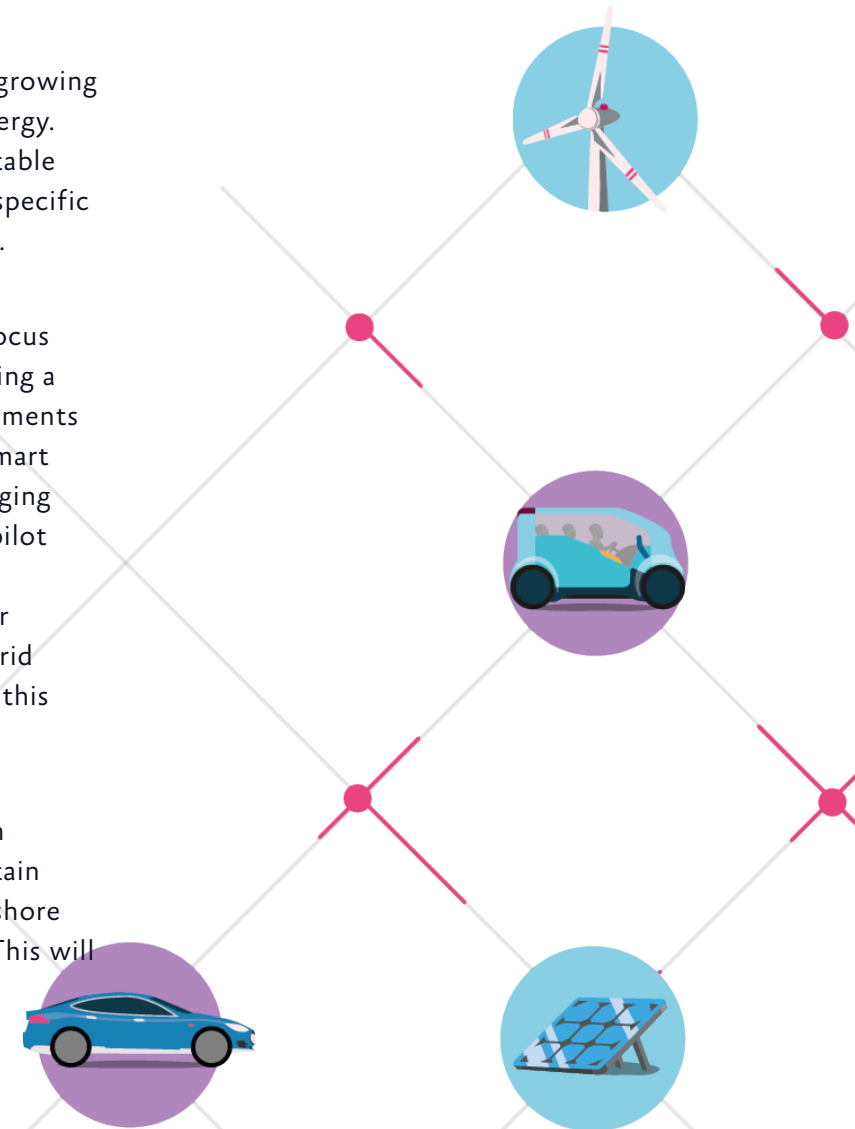
Grid operators

Finally, we have the companies that manage the grid. Tennet is responsible for the high-voltage grid, and the regional grid operators (such as Liander, Stedin and Enexis) for the medium and low voltage grid.

Tennet has to be able to maintain the grid's energy balance, coping with the growing demand for energy and the growing supply of various forms of renewable energy. The main challenge with sustainable electricity is that the supply is neither stable nor continuous. With Smart Charging, electric cars can be used to charge at specific moments; in this way, energy demand follows supply and the grid is balanced.

This is also relevant for the regional grid operators as locally generated solar power can be used immediately on site by smart charging electric cars. The focus here is therefore not national but local, with neighbourhoods powered by using a transformer. Another challenge for grid operators is how to deal with the moments when everyone needs energy at the same time; the so-called peak demand. Smart charging provides a solution by temporarily not charging electric cars or charging them less quickly. With their collaboration in ElaadNL and all kinds of joint pilot projects, grid operators play an important role in the development of Smart Charging. By making it a reliable part of grid management, this will prevent or postpone the need for major investments in reinforcing the grid. Currently, grid operators suffer from regulative restrictions; this will be discussed further in this booklet.

Incidentally, the interests of the national grid operator and the regional grid operators may conflict in certain situations. For example, Tennet may have an interest in charging as much as possible throughout the Netherlands at a certain moment, for example, when a large supply of electricity is available from offshore wind farms, but this may lead to an excessive demand for electricity locally. This will lead to different Smart Charging demands.



Flexible charging speeds in Amsterdam



Time period	Charging speed
6:30 – 18:00 hour	Normal (similar to 3x25A grid connection), and faster when sun is shining (with a maximum of 3x35A)
18:00 – 21:00 hour	Slower (flexible)
21:00 – 6:30 hour	Faster (similar to 3x35A)

Amsterdam is one of the most active cities in Europe in the field of electric transport. The city already has a large number of electric cars, electric taxis, and shared-car projects, and the number of EVs is rising sharply. In addition, it understands that there is an urgent need for locally generated sustainable energy. In March 2017, the Flexpower Amsterdam research project was started to link sustainability and electric mobility. In this test, electric cars charge faster than normal in evening hours and during the day when the sun is shining and there is a large supply of sustainably generated energy. At 'peak times', when demand is high, the public charging points charge less quickly.

The first results are positive: the system works and cars can charge faster when more renewable energy is available on the grid. Cars with more powerful charging systems charged faster during the day; older electric cars and plug-in hybrids were not affected. Ultimately, Flexpower



ensures a shorter charging time for modern electric cars.

After the first pilot, the test area was expanded from Amsterdam's centre to the districts West, New West and South. In addition, the daytime charging speed was directly linked to the actual grid

supply of solar energy. The peak times when charging was slower were found to be from 18.00 – 21.00.

Photo
Flexpower

Source: Municipality
of Amsterdam

Governments (municipalities, provinces, central government, EU)

Different levels of government also have vested interests in Smart Charging, and play an important role. The central government wants to reduce CO₂ emissions in order to combat climate change, and is working on an energy transition in which more and more energy is generated sustainably. Electric cars that are smartly charged help them achieve both objectives; they directly reduce emissions even if they still run partly on grey electricity, but also help with the switch to using sustainable electricity. As we have seen, with Smart Charging the demand for electricity can be better adapted to the supply. This prevents curtailment, switching off solar panels and wind turbines in the event of too much supply, and improves the return on investments in the generation of sustainable energy.

In recent years, central government policy has had a positive impact on the growth of electric transport in the Netherlands. There are a relatively large number of electric cars on our roads, partly due to tax incentives. The central government also determines, for example, the opportunities for providing fast chargers at service sites situated on our national road network.

Another important factor in the large growth of EVs in the Netherlands is the extensive charging station network that the Netherlands has already built up. Pioneering work was done by the e-laad foundation which installed around three thousand public charging points in almost the whole of the Netherlands in a few years, and parties like Fastned that installed a network of fast chargers. In addition, municipalities and provinces also played an important role in increasing the number of charging stations by managing the tender process, where regional governments pay for the installation of charging infrastructure in the public arena, and through permits where only the rights to install public charging stations are sold. In the Netherlands, these tenders for charging stations now also include new requirements, such as the ability to cope with Smart Charging demands in recent years and the provision of good cybersecurity. Thanks to this, not only are the numbers of charging stations growing, but also the options for Smart Charging.

Municipalities have to be able to deal with a high demand for car parking, while at the same time, facilitate the transition to electric, sustainable and clean, driving. The provision of a charging hub with many charging points where energy is cleverly distributed is an interesting proposition. The demand for car parking can also result in shorter parking times, which in turn reduces the possibilities for Smart Charging.

The central government aims to reduce CO₂ emissions and to fight climate change.





‘Laadpaalklever’ (charging point abuser) was the 2019 Word of the Year, but for Smart Charging, it is advantageous if cars are plugged in longer than they have to charge.

Less close to home but no less influential is the European Union. EU regulations have also led to emission requirements for cars by providing an impetus for the development and production of electric cars, the requirement for a universal plug (the Mennekes type 2), and by requiring Member States to install an adequate charging infrastructure. Europe also plays an important role in promoting open standards that prevent a few large companies from controlling everything, thereby ensuring consumer protection.

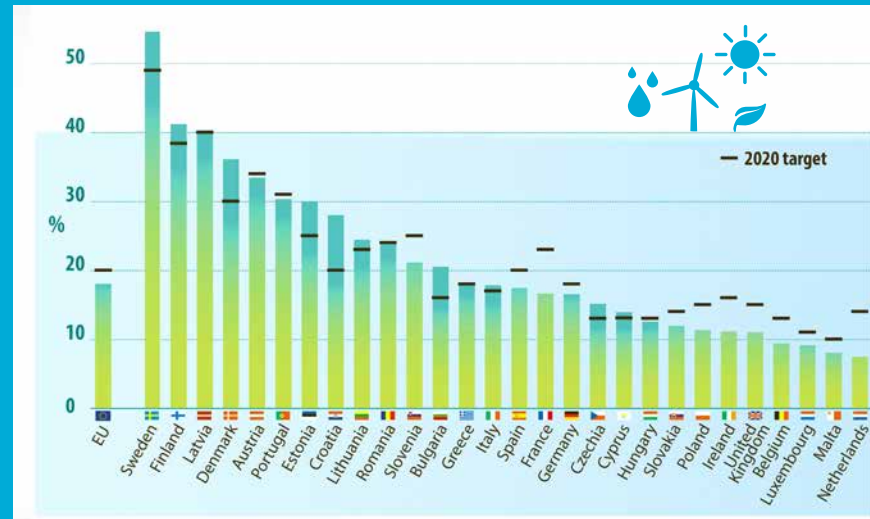
Conclusion

So we see a wide range of stakeholders with an interest in the Smart Charging ecosystem. They view Smart Charging from different interests; sometimes these match. At other times they clash. However, in the end these different interest all have to come together; an electric car must receive a clear charge/discharge control signal. Smart Charging interests and strategies are still under development, so it is vital that we jointly work together to develop the rules of the game that fulfil drivers’ wishes, the social task of achieving a sustainable energy system, and finally, ensure healthy revenue models for commercial parties.



The Netherlands in Europe: frontrunner and laggard

The Netherlands is a particular country in Europe if you look at charging electric cars on sustainable energy. On the one hand, we are at the forefront when it comes to the number of public charging stations and newly sold electric cars, on the other hand, we are at the bottom of the lists of renewable energy generation. In this area there is still much to be gained!

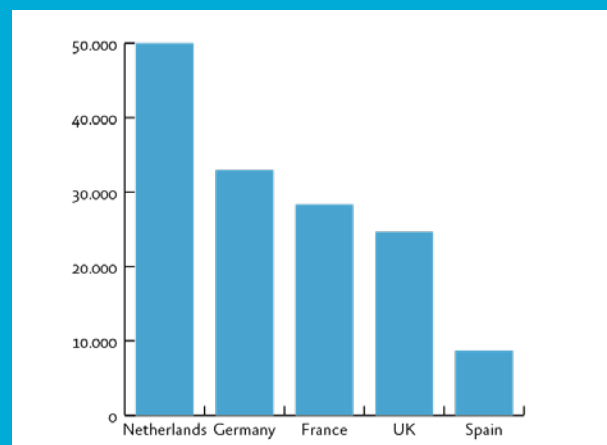


Share of energy from renewable sources in the EU Member states

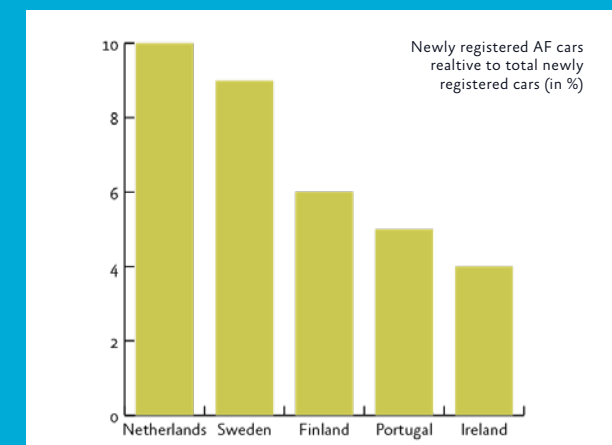
(2018, in % of gross final energy consumption)

Source
<https://ec.europa.eu>

Top 5 countries number of public charging points (2019)



Top 5 countries new registrations market share electric vehicles (2019)



Source
Europe
alternative fuels
observatory

3.4 The legal layer

The fourth layer is that of contracts, laws and regulations. With the rise of electric driving, the markets for mobility and electricity are merging. New agreements have to be made between stakeholders, and current laws and regulations have been found to have a major impact on Smart Charging.

Contracts

With regard to charging electric cars, we essentially see the following three types of agreements:

1. **Charging contract**

This is an agreement between a driver and an EMSP that regulates that the client can charge at a charging point. This can be a long-term agreement in the form of an annual contract or a contract for each time the car is charged. In the Netherlands, these options are in place for charging points in public spaces. When a charging contract is agreed between parties, the client receives a charging card with which charging sessions can be started on all public charging points. In many other situations, no formal charging contract is in place, for example, charging at the office, a hotel, or shop is often free and therefore no contract is required.

2. **Electricity consumption**

The contract for the supply of electricity is concluded between the charge point operator and an energy supplier. It regulates the supply of electricity to the charging point. Consumption is then passed on from a CPO to an EMSP as part of the charging service. New research is looking at whether it is possible to set up an energy contract between the client (possibly via their EMSP) and the energy supplier.

3. **Grid access and maintenance**

Finally, there is the primary contract between the grid operator and the charge point operator which covers grid connection installation and maintenance.

All the above contracts have conditions (or restrictions) and a price. We predict that these basic services will vary in the future, for example the charging contract may



Comparing the social cost of Standard versus Smart Charging systems

In future energy systems, in addition to reliability and sustainability, affordability will be an important core value. So even with Smart Charging it is important to look at the balance between social costs and benefits. We need a frame of reference to make this comparison, so current (standard and controlled) EV charging behaviour is generally used.

In recent years, a number of studies have been conducted in the Netherlands to gain more insights into the cost aspect of Smart Charging. In most cases, the following are considered as income:

savings through avoiding grid investments (grid extensions), savings through electricity production, and cost benefits arising from avoiding curtailment. Additional hardware and software costs for the Smart Charging infrastructure are the main cost components. In addition, we have to consider possible customer compensation for controlled charging and decharging (V2G) of his / her vehicle. According to one recent study [Smart Charging: a 'must have' with growth in electric transport, 2019, Enpuls, CE Delft and others], Smart Charging (defined as staggered charging to avoid grid congestion) would decrease the peak load by more than 2 GW - that is 20% of the expected peak load. In this scenario, Smart Charging could prevent a total of

€1.4 billion in grid investments. These benefits are a factor of 13 - 14 higher than the expected cost components. This would work out at, for an 'average' e-driver, an annual cost benefit of more than € 100.

Previous studies have been less focused on estimating the benefits of Smart Charging, but nevertheless they show that Smart Charging is always cost effective when compared to standard charging. Another study [Cheaper power due to EV Smart Charging; 2015. CE Delft] reported that with the introduction of 1 million EVs in the Netherlands, smart peak charging could prevent additional peak loads between 0.9 - 1 GWp at the LV (Low voltage) grids. Preventing this peak load could save an estimated € 200 - 236 million in grid investments.

Source [1]

Smart Charging: a 'must have' with growth in electric transport, Enpuls, 2019

Source [2]

Cheaper power due to EV Smart Charging, CE Delft 2015.

Photo
Coins

Source: Pixabay

vary in costs depending on the charging point's location. New variants of the energy supply contract will arise and possibly also of the contract with the grid operator; these variants may allow faster or slower charging depending on the availability of sustainable power generation and / or grid capacity. In certain solutions, these new contract forms will be linked to the Smart Charging control signal.

In addition to the above, numerous contract forms are possible between stakeholders. Some examples of business-to-business (B2B) contracts are those between an EMSP and a CPO on the use of charging points, between a CPO and an aggregator for optimizing electricity consumption, between car manufacturers and energy suppliers for offering a car brand charge card, and between charge point operators and employers for offering charging services at work, et cetera.

Legal conditions also apply. Examples are maximum prices, opportunities and restrictions for differentiation in prices and contracts, tax rules, et cetera. These legal conditions determine, amongst others, the ability of a grid operator to use Smart Charging.

Grid connections

We will look at the contract for grid connection in more detail. In general, the sum of the technical capacity of individual grid connections is higher than the capacity of the underlying grid. This is the result of a design choice made in the past that takes into account that not everyone needs the same amount of electricity at the





The human factor

As with any new technology, the human factor will play a crucial role in Smart Charging. Research into this is still in its infancy. We know little about the people who will be smartly charging their cars: what are their preferences and preconditions? What will move and motivate car owners to charge smartly? What will the obstacles be? And, how can we encourage people to charge smartly?

We have some indications. For example, research where cars charge more slowly outside peak hours shows that users find it important to have a 'charge-me-now' button with which they can still charge immediately if necessary, however this was hardly used. This type of research provides important insights into how Smart Charging could work best in practice.

Asking current electric car drivers questions and investigating their behaviour is simply not enough: today's users are not representative of future users. For example, the demography of people who drive electric will broaden from a relatively small group of mainly highly educated men (in particular lease drivers) to a better reflection of the population.

We still know little about the people who will be Smart Charging their cars: what are their preferences and preconditions?



same time (so-called non-simultaneity). In the Netherlands, the 3x25A connection is a particular issue as the client has 17kW power available, and the underlying grid has in many cases been calculated using an average 4 kW simultaneous load.

The current grid contracts do not contain any incentives to use the electricity grid efficiently and thus prevent overloading. For example, Smart Charging could be stimulated by taking a different approach.

As noted earlier, the capacity available in the selected grid is important when determining Smart Charging strategies. In most cases, the aim is to make optimum use of grid capacity. With the development of electric cars, grid operators are being forced to think about alternatives to existing connection contracts. Three main solutions are emerging, all with a common denominator: the terms and conditions of the existing connection contract have to be reconsidered.

- connection with flexible capacity
- connection with flexible rates
- connection with bandwidth

Connection with flexible capacity

This solution entails determining a variable capacity profile. This profile is defined per time period and has a number of variants. It has a fixed monthly fee. The effect of different profiles is tested during experiments:

- Less power at peak periods; extra power outside peak periods.
- Profile is updated periodically. Different profiles are possible per workday, weekend, month or season. One could start with static profiles, which can eventually become dynamic profiles.
- In addition to individual connection profiles, group profiles can be developed for charging points connected to the same electricity cable or to neighbourhood transformers.

Connection with flexible rates

This model is based on different rates at different day time periods. These time blocks are related to the peak and off-peak hours of available capacity; flexible rates will be applied depending on the available capacity. In short, the rates are low at

Testing the effectiveness of different solutions.



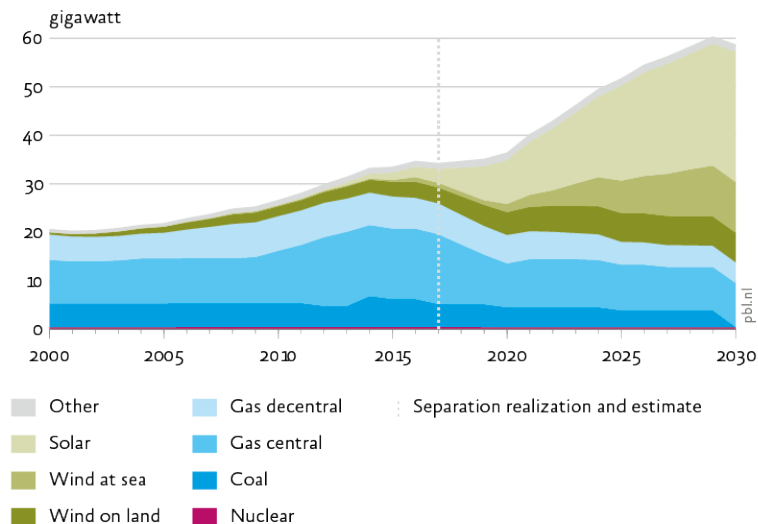
In 2030, two thirds of our electricity will be generated from renewable sources

Predictions related to electricity production are generally unreliable. The northwest European electricity market can be more or less viewed as an integrated 'supranational' market. Developments in other countries therefore have a great impact on the

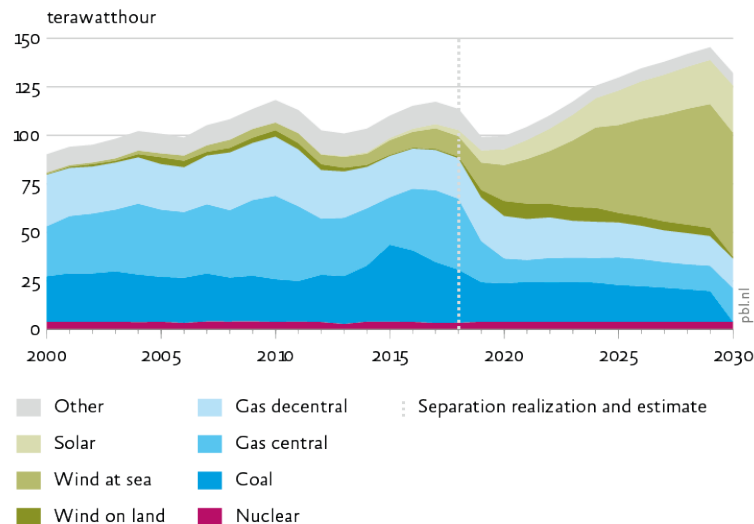
Dutch electricity sector. We see that the installed capacity in the Netherlands will almost double from the current 30 GW to 60 GW in 2030. It is notable that a relatively large amount of installed power is required for solar production. Moreover, it is estimated that in 2025,

more than half of Dutch electricity will come from renewable sources. In 2030, five years later, it is expected that more than two-thirds of Dutch electricity will be from renewable sources

Installed Power in Netherlands



Electricity supply in the Netherlands



Source
Climate and Energy
Outlook 2019

times with high capacity, for example at night, and high at times of low capacity, for example during the evening peak.

The effect of different rates is tested. Experiments started with a static profile which is updated periodically. At a later phase, when more local sustainable energy is generated, it is expected that this static profile will develop into a dynamic profile.

Connection with bandwidth

In this variant, small-scale consumers receive a contract in which a bandwidth is agreed, for example 4, 10, or 17 kW for a fixed monthly sum. Any consumption within the bandwidth is covered by the monthly payment. If the client uses more than the agreed bandwidth, an additional invoice will be issued, calculated per kWh.

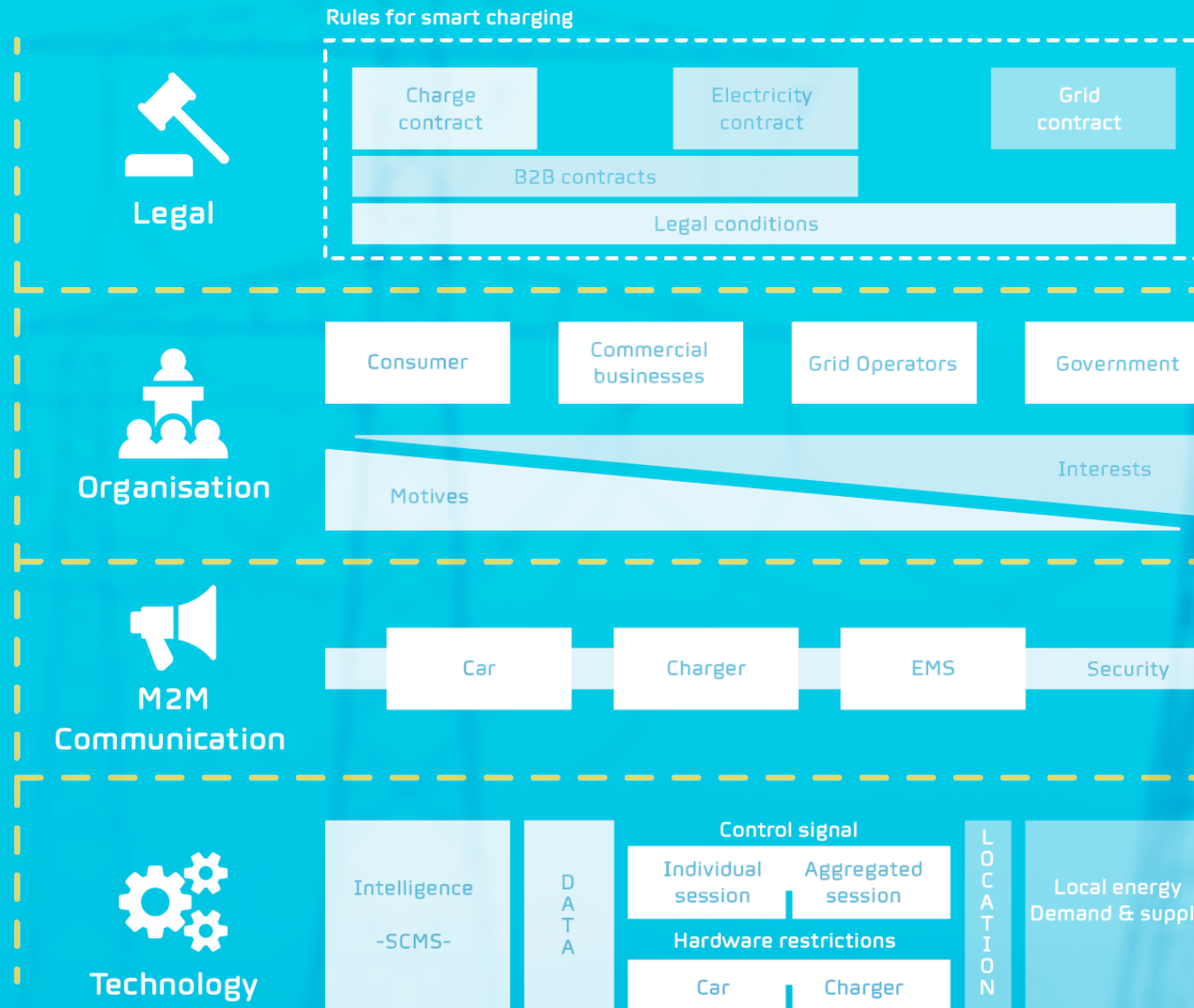
Ultimately, after a period of research and experimentation, a choice will have to be made for the shape of future grid contracts. As grid operators are regulated companies, the tariffs are set politically within the framework of the Energy Act. The choice of contract will have major consequences for the expected surge in Smart Charging and variants.

Conclusion

In the legal layer, the different agreements, regulations and laws will determine the future direction of Smart Charging. New market models will ensure coordination of capacity supply and demand in the longer term. The use of Smart Charging services requires a market mechanism in which stakeholders, including the grid operators, can work together, for example, for unlocking either voluntary or enforceable flexibility. Agreements can be made about which choice should be made if there is a risk of grid overload and being able to charge with less power. Because Smart Charging is relatively new and in a phase of rapid development, there are a number of challenges to be met: we have to remove barriers and develop effective laws and regulations.



Four layer model for Smart Charging



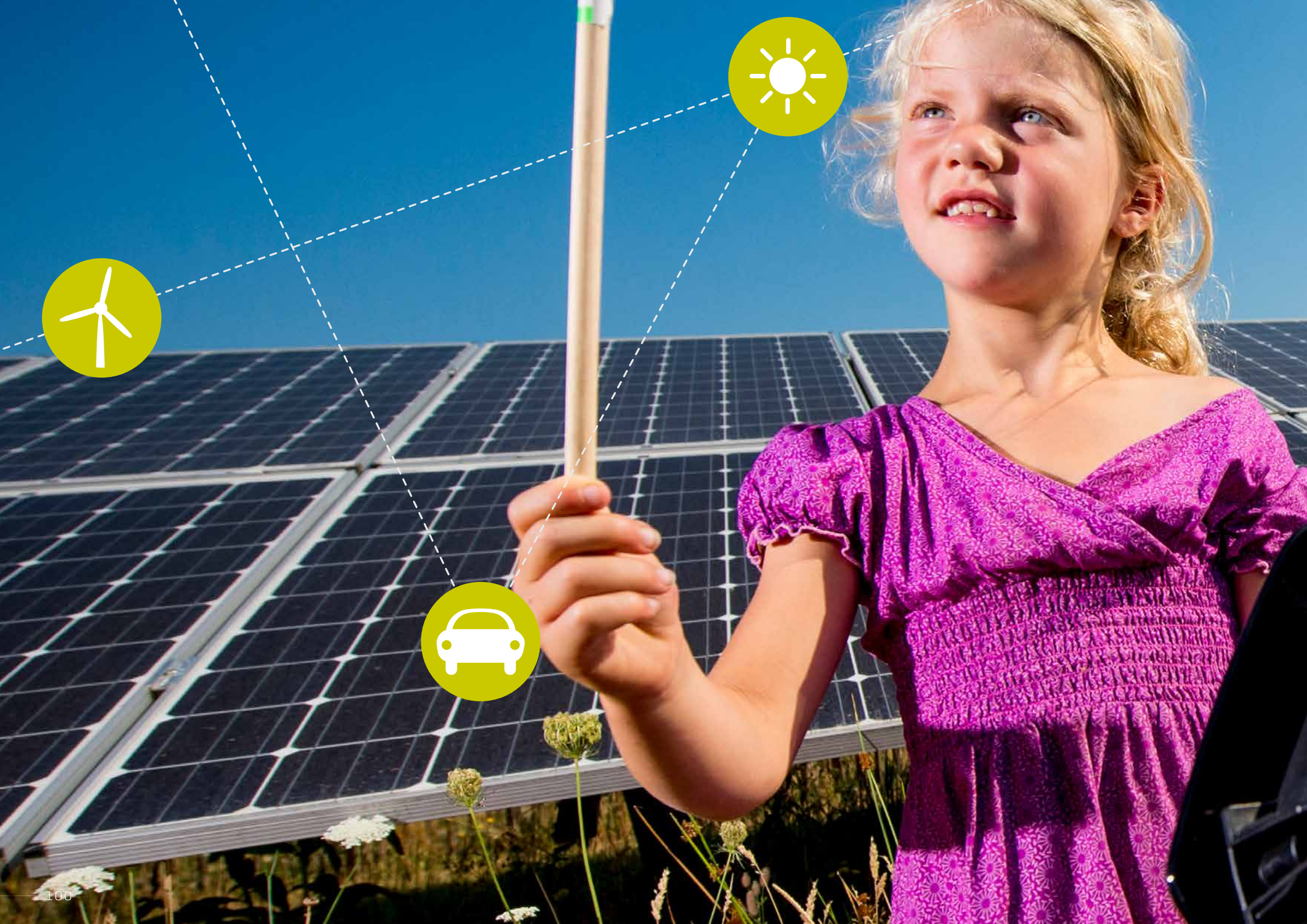
Smart Charging is the solution!

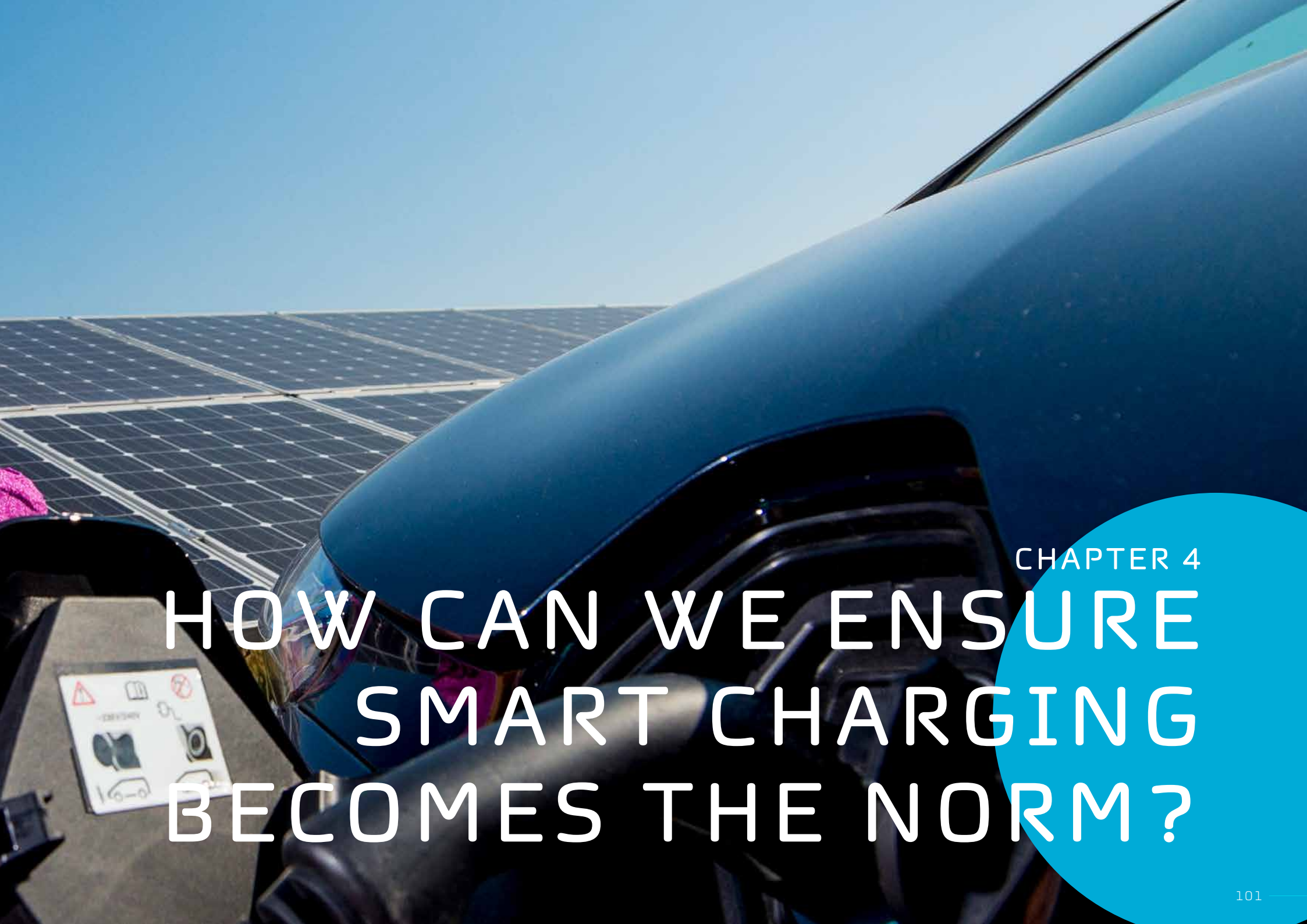
After having explored the four layers, a number of conclusions can be drawn. To be able to sustainably charge electric cars on a large scale, we need Smart Charging. This is, simply, about managing electric car charging and discharging. Great efforts are needed for us to successfully apply Smart Charging. The technology, hardware and IT communication, must make steering possible, communication must be secure via open standards, and a lot of data are required for customization. Many stakeholders will want to apply different forms of Smart Charging based on different wishes and interests. Sometimes these interests will coincide, but often they won't. We therefore need rules and regulations to determine who can manage what and when in the Smart Charging ecosystem.

There is still a great deal to be done before Smart Charging can be used efficiently and effectively on a large scale. This will be discussed further in the final chapter.

Because Smart Charging is still relatively new and in full development, there are many challenges to be met.





A blue electric car is shown from the side, parked in front of a large array of solar panels. The car is connected to a charging station, and a charging cable is visible. The solar panels are arranged in rows, and the sky is clear and blue. The text "HOW CAN WE ENSURE SMART CHARGING BECOMES THE NORM?" is overlaid in white, bold, sans-serif font. A blue circular graphic element is on the right side of the text.

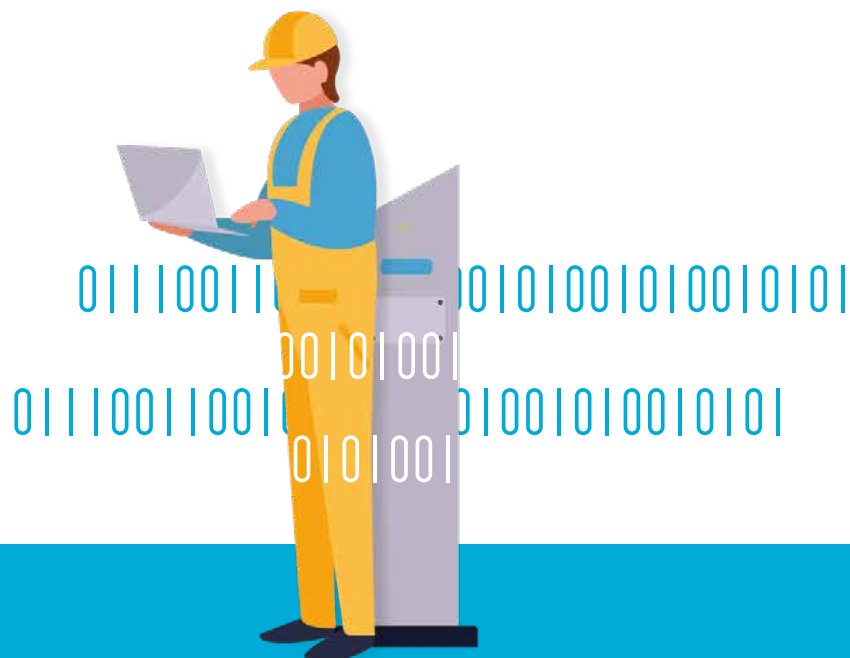
HOW CAN WE ENSURE SMART CHARGING BECOMES THE NORM?

CHAPTER 4

Now we have explored all sorts of aspects related to Smart Charging, it's time to list what we still have to do to make Smart Charging a success so that we can sustainably and effortlessly charge millions of electric cars.

First of all, we still have to research, explore and gain experience in both small-scale and large-scale research projects; we're currently in the middle of this. Many studies and projects are still ongoing or have yet to start. There's also a lot more to investigate. Many stakeholders are working together with the ElaadNL knowledge and innovation centre. In addition, grid operators are using the limited options available to them under the current legal framework, the so-called experimental space. Only in this way can they properly explore the different variants of Smart Charging. Paying for flexibility, variable rates, variable connection capacity, and other variants of Smart Charging are not yet possible under existing legislation and regulations.

In general, at this moment the existing legislation and regulation in this field are inadequate to cope with the emergence of electric cars and locally generated sustainable electricity. A great deal still has to be done! We therefore conclude this Guide with a to-do list. Which ten points are essential for making Smart Charging a success?



The To-Do list.



Fully test electric cars before they plug into the grid

Currently, European type approval of electric cars is conducted by the certifying authorities, in particular with regards to vehicle safety. Additional tests are performed on a voluntary basis, for example at the ElaadNL test lab, for interoperability (being able to charge on all charging points), power quality (grid pollution) and Smart Charging (monitoring of control signals). In fact, every new electric car should be tested on all these aspects, not just on road safety.

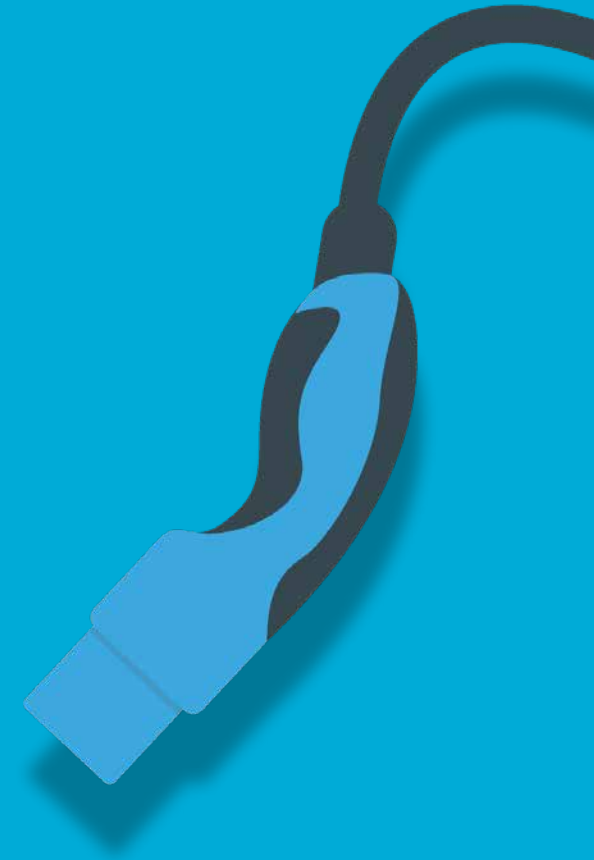
By converting from alternating current to direct current, electric cars can both pollute and improve grid quality. Charging on 1 phase can lead to unbalanced phases, therefore charging on 3 phases is preferable, where possible. Where EVs support Smart Charging control signals, the car can make a positive contribution to balancing the electricity system.

Action is needed in the short term. The electric cars, vans, trucks and buses that are now being made and are being launched on the market will be on the road for many years to come. Currently, the average lifespan of a passenger car is around sixteen years.



Roll out a Smart Charging infrastructure with optimum capacity

By connecting the charging station to the grid with the largest possible capacity connection, we can create maximum flexibility for Smart Charging. An electric car can be charged faster at times when this is desirable if there is greater capacity. Faster charging reduces the grid load at peak hours, provided that the correct Smart Charging regime is linked to this.



Unfortunately, a higher capacity connection is more expensive than a lighter one. This is partly due to the difference in capacity that has to be reserved in the grid to meet the peak load. If grid operators can combine Smart Charging signals with the capacity rates that they are allowed to charge, then the e-driver will receive a much 'faster' charging station and we can use the electric car even better to request power when desirable .



Offer regional grid operators the opportunity to make flexibility agreements

Take advantage of the abundant grid capacity. By charging EVs at smart moments, for example at night or in the weekend, we can optimally use available grid capacity. Without Smart Charging, the further growth of electric driving will lead to greater peaks in power demand, while at the same time charging electric cars with Smart Charging offers a great deal of flexibility for managing the grid and for the use of solar and wind energy as it is produced. Options for making specific agreements for the use of Smart Charging to prevent peak overloads (congestion management) are currently limited legally, outside approved experimental conditions.

We need to give regional grid operators room to make agreements for voluntary congestion management on condition that stakeholders support Smart Charging signals. We also need to give them the power to develop and validate new different contract models for a grid connection: flexible capacity agreements, a bandwidth model, and variable grid rates. As the digitization of the power grid progresses further, this profile can be made dynamic. In the long term, a dynamic profile can be integrated into a tariff solution. Experience has also been gained with the marketplace architecture, however it appears to be less suitable for this purpose.



The Smart Charging game plan

The different Smart Charging perspectives can be contradictory. Clear prioritization is required; it must be clear who can control what and when. Regulation is definitely needed.

It is important that it is clear who determines how an electric car's battery can be used for Smart Charging and which Smart Charging initiative has priority. For example, under current regulations, nowhere can it be found that the e-driver is the one who gives permission for the use of his electric car and under which conditions (time of departure, minimum battery capacity, et cetera.). Moreover, exceptions may be needed. For example, preventing local grid overload is more important than other factors, as currently we have few alternatives and we need to ensure grid reliability.

Charge Point Operators also need to provide space for Smart Charging, even though this may not always run parallel to electric car owners' wishes. The Charge Point Operator of (semi) public charging points has a different interest than, for example, that of the e-driver, Tennet or the regional grid operator. The Charge Point Operator usually has a business model for charging points based on maximizing the occupation of the charging point and optimizing the deployment of the available charging capacity. Due to Smart Charging initiatives from other players, a car may no longer be connected to a charging point for a longer period, and therefore unable to use Smart Charging options.

In short, we have to clearly regulate Smart Charging in order to make it successful.



Ensure data required for Smart Charging

To make Smart Charging possible, communication is needed between all the stakeholders in the chain. This concerns, for example, communication about the state of charge (size of battery and the extent to which it is charged), the time of



departure (or the time the consumer needs the battery to be fully charged), the type of electric car, the charging speeds (threshold values for the minimum and maximum power for charging) and e-driver preferences (for example, minimum range that must be available). At present, access to this data (in particular the state of charge) has not yet been arranged and laid down in a technical standard. Specific bilateral agreements must be made with car manufacturers to unlock the state of charge.

Ensure open access and promote the use of open standards in the Smart Charging ecosystem

In a successful Smart Charging ecosystem, all kinds of devices can 'talk' to each other regardless of type or brand. Solar panels, home energy management systems, charging points for electric cars and back offices must all be able to communicate with each other problem-free. By using open standards a worldwide roll-out is possible and we can prevent lock-ins and further develop the system. This can be reinforced by requiring the use of open protocols in tenders for the new charging infrastructure.

Cyber security: protecting the e-driver and grid

As electric cars and Smart Charging become a crucial part of the electricity system, the exchange of data and measurements must also be safe and reliable. The system has to be completely secure to prevent access by unauthorized parties via hacks. The need for better (cyber) security matches consumer desires for an open market with freedom of choice in combination with a seamless service. The charging infrastructure needs to be defined as a critical infrastructure. Tenders for public charging points need to commit to the cyber security requirements set by ENCS and ElaadNL.



Optimise energy storage in electric vehicles

As the batteries of the electric vehicles grow in capacity, there is increasing room for Smart Charging. In addition to its use for mobility, the battery can also be used as local storage within the electricity system. At the moment, consumers can virtually 'store' self-generated electricity on the grid, as they only pay for the balance of kWh that they purchase from the grid on an annual basis (within a set limit). This so-called netting arrangement has proven successful in stimulating the purchase of solar panels. However, it has eliminated the incentive to optimize the production of sustainable electricity and local use. After all, there is no difference in cost between temporary storage, for example in electric car batteries, of electricity for your own use at a later time and feeding the grid with home-produced electricity. The netting scheme will be revised in 2023. We need to ensure that the new netting scheme includes incentives for Smart Charging.



Price transparency will improve participation in Smart Charging initiatives

Greater transparency for e-drivers about the current costs of electric driving will ensure that they can better assess the financial benefit of a Smart Charging initiative. At the moment the structure of the underlying costs of electric driving is often unclear. The e-driver pays a contribution to the energy supplier (home charging) or to the Electric Mobility Service Provider (public charging), depending on the charging location, but only sees this afterwards. As a result, e-drivers are unaware of costs made at a specific time. Lease drivers who often only use public charging points often have even less insights into their costs as the leasing company is responsible for payment. Electricity tax also weighs heavily in this equation, as the higher the total energy consumption at a location, the lower the tax per kWh. There is still a long way to go in this area. Better insights into the prices at a given moment will reinforce Smart Charging options as any savings become more transparent.





Improve financial incentives

Motorists currently pay a flat rate for their electricity consumption or have a day/night rate. Smart Charging offers the opportunity to better align their electricity consumption with the availability of (sustainable) electricity by charging at times 'cheap' electricity is available. And if V2G is applied, it will be possible to resupply energy at a different time.

Flexible rates for electricity use can provide a price incentive to better match consumption with supply. In practice, this is only currently applied on a small scale. Central government, municipalities and provinces could pass on this incentive to e-drivers via tenders for the charging infrastructure. Cheaper charging when electricity prices are low.

However quarterly pricing only seems to result in a limited price incentive as the majority of the costs per kWh consist of taxes (energy tax and VAT). As a result, any advantages of quarterly pricing strategies remain limited.

A special situation arises if the electric car is used for bi-directional charging (V2G). For example, if the car is first charged using a public charging station, and then supplies energy to the grid, and then this is charged back into the car. The e-driver would then have to pay energy tax several times for the same power. This has a direct impact on Smart Charging: it is currently not financially attractive for e-drivers to make their electric car available for bi-directional charging as they are taxed for their energy use at least twice: this must come to an end.

Finally

We still have a long way to go to make Smart Charging the norm and to be able to charge millions of electric cars effortlessly and sustainably. However, the 10 points of our To-do list show we can come a long way.

We call on everyone involved in the evolving Smart Charging ecosystem to contribute to this, in particular national and European governments. Existing laws and regulations were set in a very different period, and should not stand in the way of a beautiful, sustainable innovation such as Smart Charging.

ElaadNL enjoys working together with all the stakeholders involved in Smart Charging and will continue to contribute to research and further innovation. In this way we strive to make the electric car a successful part of our future fully sustainable energy system!



List of abbreviations

A Ampère

AC Alternating Current

ADR Automated Demand Response

CPM Charge Point Manufacturer

CPO Charge Point Operator

CS Charging Station = EVSE Electrical Vehicle Supply Equipment

DC Direct Current

DLT Distributed Ledger Technology

DSO Distribution System Operator

EMS Energy Management System

EMSP E-Mobility Service Provider

EV Electric Vehicle

EVSE Vehicle Supply Equipment = Charging Station

GW Gigawatt

GWh Gigawatt hour

HV High Voltage

Hz Herz

kW Kilowatt

kWh Kilowatt hour

LV Low Voltage

MV Mid Voltage

MSP Mobility Service Provider

OCHP Open Clearing House Protocol

OCPI Open Charge Point Interface

OCPP Open Charge Point Protocol

OEM Original Equipment Manufacturer (car manufacturer)

OSCP Open Smart Charging Protocol

TSO Transmission System Operator: national grid manager (Tennet)

TWh Terawatt hour

V2G Vehicle to Grid

V2H Vehicle to Home

V2X Vehicle to Anything



About ElaadNL



The ElaadNL knowledge and innovation centre researches and tests possibilities for Smart Charging: reliable, affordable and sustainable charging of electric cars. ElaadNL is an initiative of the joint Dutch grid operators.



ElaadNL is an initiative of:



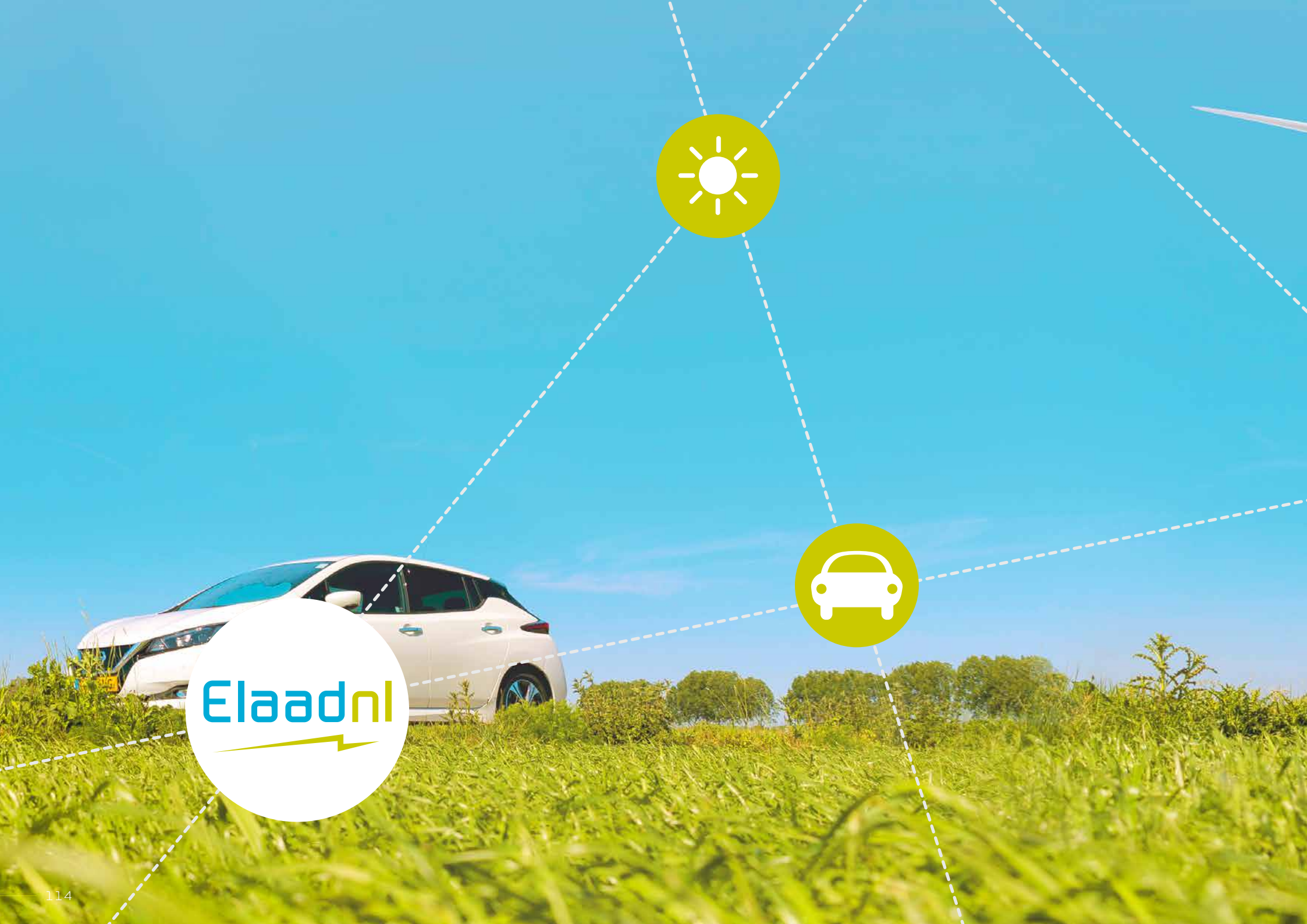
The Smart Charging projects described in this publication are conducted by a large group of enthusiastic partners who we have not all listed for readability purposes. We would like to express our thanks and appreciation for everyone's commitment!



English edition

This is the English edition of the Smart Charging Guide. We have adjusted the original text based on feedback received on the first Dutch-language edition published on 12 September 2019.

This current edition of the Guide focuses primarily on the Dutch situation. In the near future we would like to work with our international partners and produce an international version.



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