The impact of electric vehicles on the energy industry

This study is part of the Austrian Climate Research Programme

Table of Contents

The aim of this study is to provide an analysis of the impact that electric vehicles would have on the Austrian energy industry. The assumption that was made for this study is that purely electric vehicles were to be examined, meaning vehicles running on batteries without combustion engines. Taking as a basis data from 2007, the study examines the nature of the impact in the years 2020 and 2030. The underlying assumption of the study is that electric vehicles will make up 20% of the total number of passenger cars, light duty vehicles and two-wheeled vehicles existing on the market (hereinafter referred to as "20% coverage") where all registered vehicles are the data basis.

Based on a traffic impact analysis, the following issues were examined in this study:

- Impact on electricity generation through the charging of electric vehicles
- Impact on the public power grid
- Changes to the Austrian carbon footprint
- Economic analysis including a cost-benefit calculation

1 Results

- 20% coverage (approx. 1 million electric vehicles) would lead to an increase in power consumption of approx. 3% and would not require the construction of further power plants.
- An electricity consumption analysis over the course of an average day has shown that the power grid infrastructure currently in place provides sufficient capacity; adaptations to the distribution networks would be only required with regard to charging points. This means that 20% coverage would not require network reinforcements.
- Introducing electric vehicles to the Austrian market would require the installation of approx. 16,200 electric vehicle charging points. Should, however, electric vehicles be mainly introduced in cities, approx. 2,800 charging points would need to be installed. These installations plus network connections would require investments amounting to EUR 111m and EUR 650m, respectively.
- Assuming an electricity capacity mix corresponding to the amount of electricity generated as of today, car emissions would be reduced to 40 g/km. This would amount to a reduction of two thirds as compared to the emissions caused by conventional vehicles.

- The carbon footprint (total carbon emissions produced in Austria) could be reduced by 2 metric tons of CO2, which would mean a 16% reduction in carbon emissions caused by passenger cars, light duty vehicles and two-wheeled vehicles (this figure is based on an electricity generation mix corresponding to the electricity generated as of today).
- With regard to the national economy, the introduction of electric vehicles would result in a positive net effect of approx. EUR 1.3bn. While this effect would have a more or less neutral impact on the national budget, it would be highly advantageous for investments, resulting in a positive net effect of EUR 1bn (which is approx. 10% of the total industry volume as of today).
- In total, electric vehicles have a higher degree of efficiency than conventional vehicles. 20% coverage would lead to an energy reduction of approx. 8.4 TWh, which would be approx. 37% of the energy efficiency target set for 2016.

2 Analysis of the traffic industry

Based on the data and information available, vehicles were grouped into the following categories:

- Passenger cars
- Two-wheeled vehicles (motorbikes, small mopeds, mopeds)
- Light duty vehicles

The calculations were based on the assumption that the average distances travelled (in kilometres) for each vehicle category remain constant. This assumption can be explained by the fact that statutory regulations are very likely to cause a pro-rata shift towards public transport, thereby compensating for the rising number in vehicles.

Table 1: Number of kilometres travelled per trip purpose, 2007

Average number of kilometres travelled per year	
Passenger cars	15,000 km
Light duty vehicles	15,000 km
Two-wheeled vehicles	4,500 km

Source: PwC analysis

The average number of kilometres travelled per year served as a basis for determining the number of vehicles and kilometres travelled in 2020. These calculations have shown that 91% of all kilometres are travelled passenger cars (both for business and private purposes). 6% of all kilometres are travelled by light duty vehicles and 3% by two-wheeled vehicles. The results for the years 2007, 2020 and 2030 are shown in the table below:

Table 2: Number of vehicles and kilometres travelled in 2007 and 2020

Source: Statistik Austria, PwC analysis

Volume of vehicles and kilometres travelled		2007	2020	2030
Passanger vehicles	Volume	4,245,583	4,443,826	4,589,583
	km (in billions)/year	63.68	66.66	68.84
Two-wheeled vehicles	Volume	435,905	456,259	471,224
	km (in billions)/year	1.96	2.05	2.12
Light duty vehicles	Volume	297,888	311,798	322,024
	km (in billions)/year	4.47	4.68	4.83
Total	**Volume**	**4,979,376**	**5,211,882**	**5,382,831**
	km (in billions)/year	**70.1**	**73.4**	**75.8**
Total 20% coverage (electric vehicles)	**Volume**	**995,875**	**1,042,376**	**1,076,566**
	km (in billions)/year	**14.0**	**14.7**	**15.2**

Furthermore, each individual vehicle category was studied for the following travel purposes:

- Commuters – daily travel to and from work
- Business trips – work related journeys
- Private/shopping – private shopping trips
- Education – daily trips to and from learning institutions, schools, etc.
- Leisure time – daily trips related to sporting activities, visits, etc.

The chart below shows the overall kilometre allocation in relation to the different travel purposes.

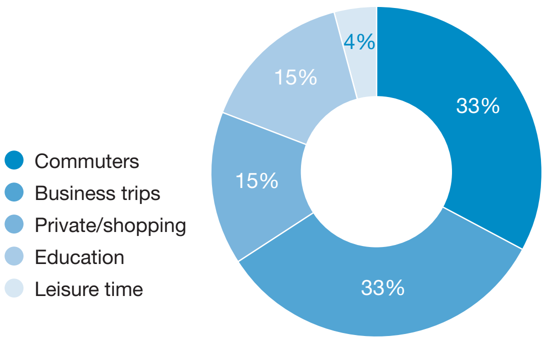


Figure 1:
Number of kilometres covered per travel purpose in 2007

Source: PwC analysis

An average working day was used for the purpose of analysing hourly traffic volumes. This traffic volume analysis was taken as a basis for analysing battery charging and, consequently, the effects thereof in relation to the average daily use of electricity. Figure 2 shows hourly traffic volumes according to the individual travel purposes.

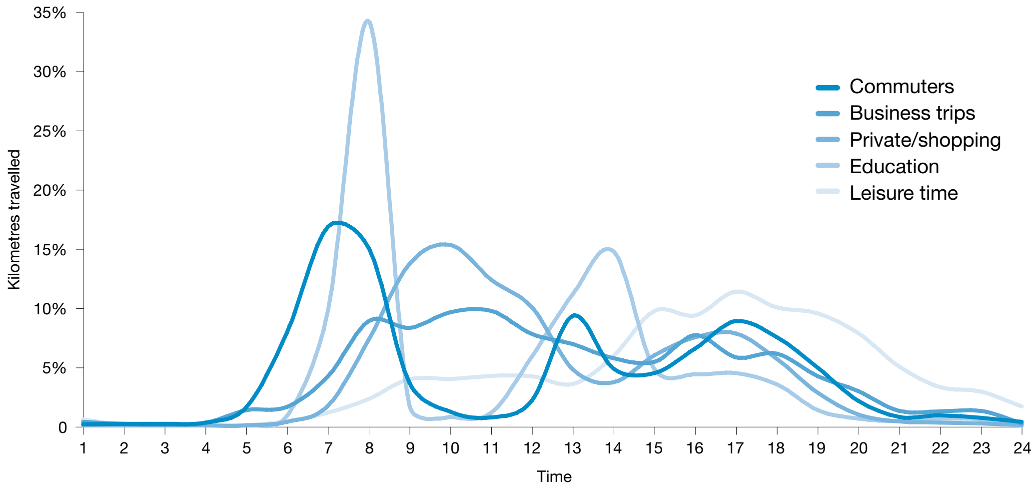


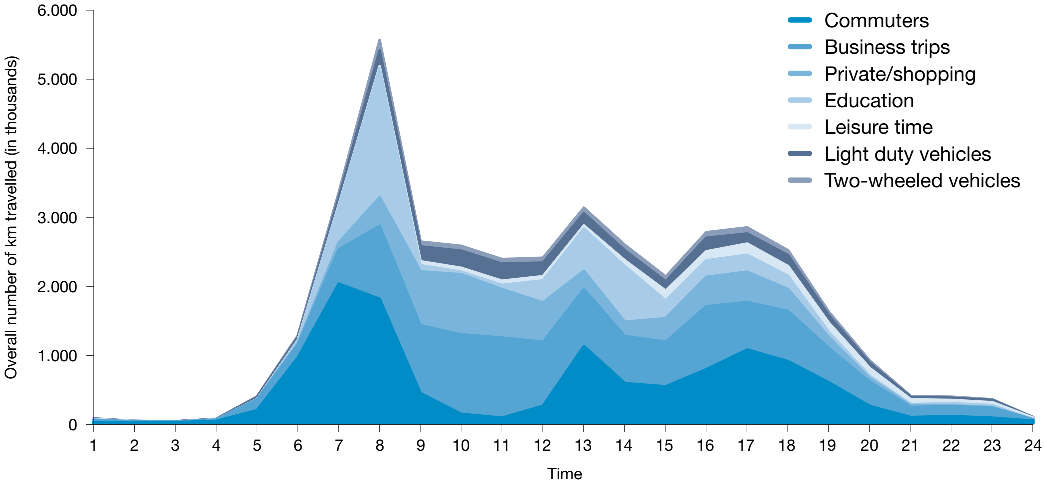
Figure 2:
24 hour traffic volume profile according to individual travel purposes

Source: Herry Consult

The figure below shows the traffic volume profile for all category types. It illustrates a distinctive peak at eight o'clock in the morning. This is mainly caused by rush hour commuter traffic. A further peak can be seen at six o'clock in the evening, at which time both commuter and leisure traffic come together. There is an additional peak at 1pm, which is also caused by commuter traffic.

Figure 3:
Cumulative 24 hour traffic volume profile

Source: Herry Consult



3 Electric vehicles

The present study is based on the assumption that purely electric vehicles (vehicles running on batteries only) were to be examined. It did not take alternative engine concepts such as hybrid or fuel cell vehicles into consideration. On the basis of data collected by PwC, the following key parameters were defined:

Passenger cars:
- Average range: 200 km
- Battery charging capacity: 30 kWh

Light duty vehicles:
- Average range: 250 km
- Battery charging capacity: 50 kWh

Two-wheeled vehicles:
- Average range: 80 km
- Battery charging capacity: 4 kWh

4 Energy industry

From an energy industry perspective, the following key factors are of significance:

- It is important to determine the amounts that are required for the charging of batteries.
- It is important to ensure adequate power transmission and transmission capacities.

With regard to electricity generation, it is important to establish how electricity consumption will develop in the future and which other potential forms of electricity generation, be they hydropower, fossil fuel power plants or renewable energy sources, can be implemented in the future. Battery charging levels required can be calculated on the basis of the number of electric vehicles on the market as well as on the basis of traffic volume. Batteries will be charged via the public power grid. As energy is lost during the charging process, there will be less electricity in the battery compared to the amount that has been charged from the power grid. Analyses based on charging stations available on the market have shown that the loss factor for an average battery charging station is 20%. This loss factor was taken into consideration in the calculations which are set out below.

The table below shows the required battery charging amounts that would have to be provided by the energy industry. Assuming an increase in electricity consumption of 2% per year, the said battery charging amounts can be taken to illustrate the respective shares in electricity consumption in 2020 (3.0%) and 2030 (2.6%).

Battery capacities 20% coverage			
		2020	**2030**
Passenger cars	GWh	2,400	2,478
Light duty vehicles	GWh	224	232
Two-wheeled vehicles	GWh	25	25
Total electric vehicles	**GWh**	**2,649**	**2,736**
Share in electricity consumption (+2.0%)		3.0%	2.6%

Table 3:
Battery charging amounts for 2020 and 2030 (20% coverage)

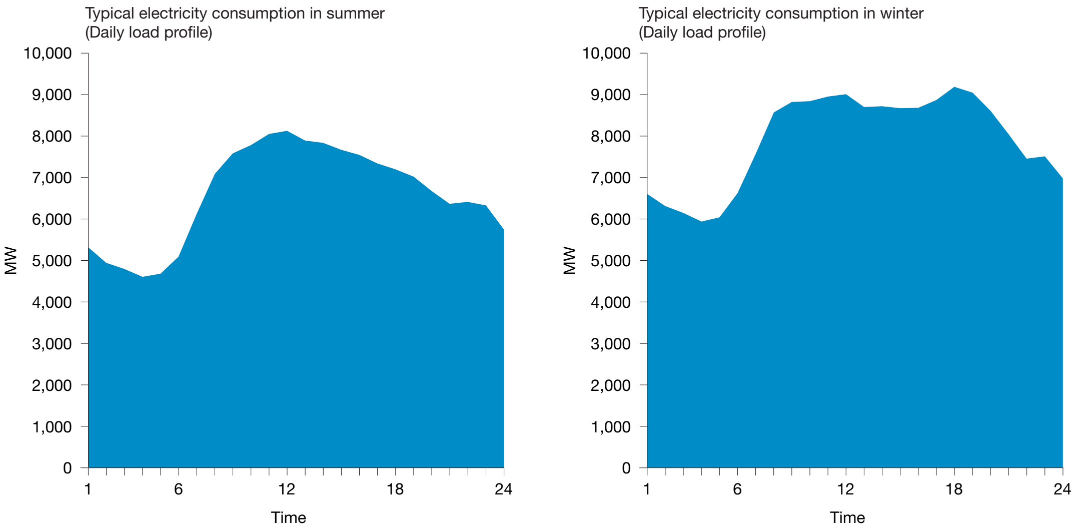
Source: PwC analysis

In order to study the effects on daily electricity generation, load profiles (which show electricity consumption over a 24 hour period) based on data provided by E-Control were drawn up for a typical summer day and a typical winter day and taken as reference points.

Average electricity consumption in summer is characterised by relatively little electricity consumption at night, with electricity consumption being at its peak at midday, after which point it continuously falls until picking up again at around six o'clock in the morning. Electricity consumption in the winter months, on the other hand, is characterised by considerable peaks at midday and in the evening, with electricity consumption levels falling only to a minor extent over the course of the afternoon.

Figure 4: Typical electricity consumption over the course of the day (load profile) for summer and winter

Source: E-Control



Batteries used in electric vehicles can be charged using conventional household plugs, requiring an average charging time of seven hours. The charging time can be reduced to a minimum of 30 minutes where specific charging points are available. For the study at hand the assumption was made that the average time required for recharging completely empty batteries would be seven hours.

The level of electricity consumption required for the charging of batteries was added to daily electricity consumption. For the purpose of this analysis the general assumption was made that every vehicle would be charged in the evening and overnight, and that during the day an electric vehicle would only be taken to a charging station if its batteries were completely empty.

The figures below shows the total load curves over the course of one day. The load curves show that based on the average daily number of kilometres travelled, it would be possible to charge batteries overnight, thereby ensuring that the electric vehicle would be fully charged and ready in the morning.

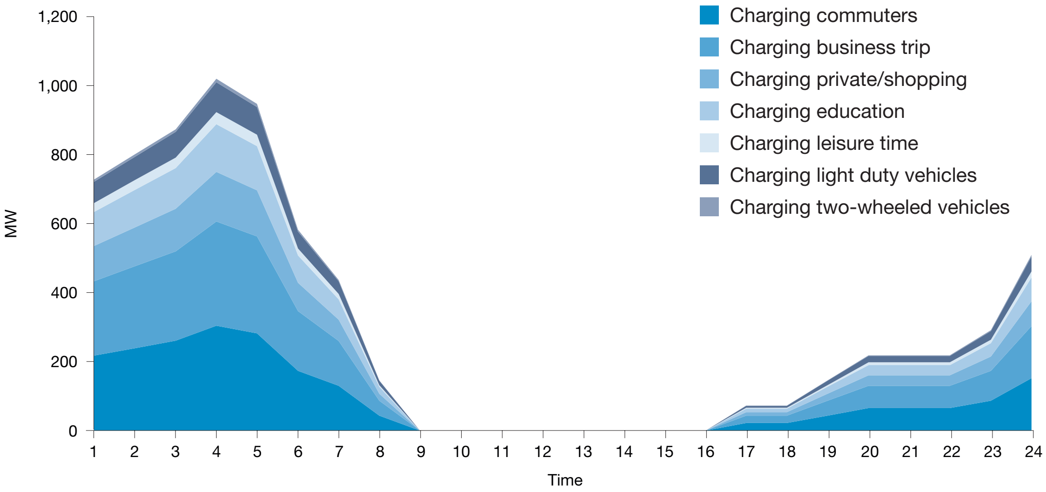


Figure 5:
Total load curve over one day (24 hours) (20% coverage)

These load curves are now added to the electricity consumption profile (load profile) through which a total daily electricity consumption amount can be deduced (total load profile). A total load profile is shown below on the basis of 20% coverage and the additional electricity requirements brought about through the charging of batteries. Electricity consumption levels are set on the basis of an average summer day in 2020. A further observation that can be made is that the additional amounts of current during the night do not exceed the daytime peak amounts. Data are shown in hourly grids, meaning that performance data can be shown on an hourly basis. The power grid would ultimately have to be structured in such a way as to be able to cope with the delivery of electricity when peak demand occurs, and it can be clearly seen from above that the power grid would not have to be further upgraded and strengthened due to this additional delivery of electricity. A further positive effect which results from this is that electricity consumption would be raised during the night, meaning that power stations would be operated on a more constant level, which in turn would lead to greater economic efficiency.

Figure 6:
Overall electricity consumption incl. potential energy for a typical summer day (20% coverage, 2% electricity consumption increase)

Source: PwC analysis

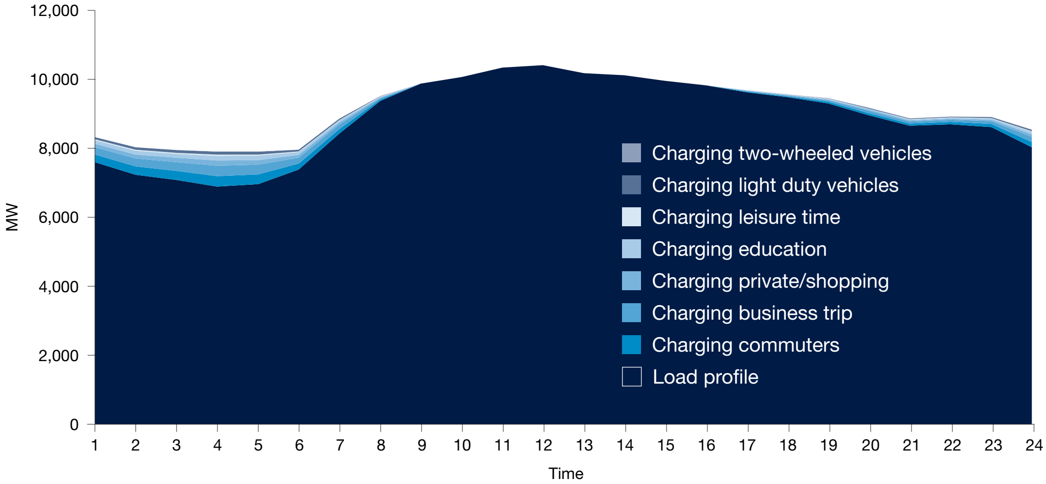
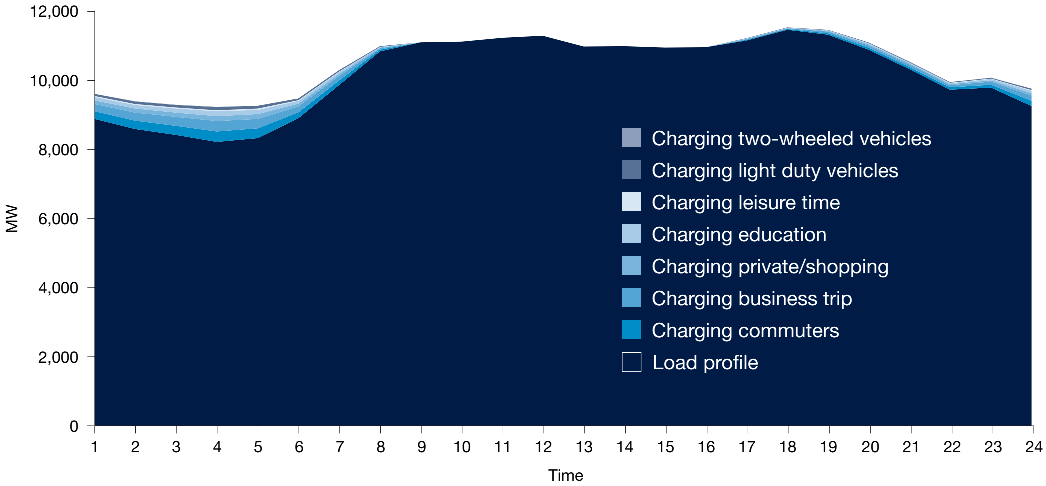


Figure 7:
Overall electricity consumption incl. potential energy for a typical winter day (20% coverage, 2% electricity consumption increase)

Source: PwC analysis



5 Contribution of electric vehicles to energy industry (VG2 concept)

When electric vehicles are not needed, the electricity saved from the batteries could be resupplied to the power grid. The concept of resupplying electricity taken from electric vehicles to the power grid is known as the ‘V2G’ or ‘Vehicle to Grid’ concept.

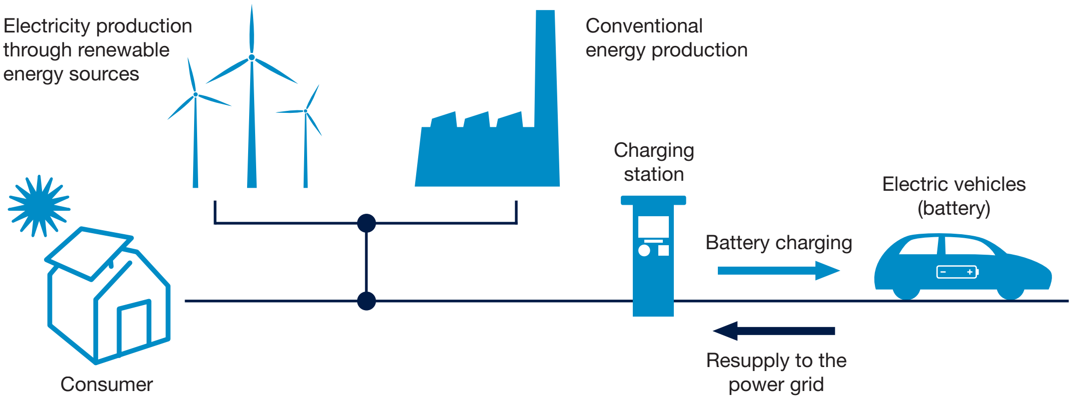


Figure 8: V2G concept

This could be of particular interest to vehicle owners who only need their vehicles at particular given times (commuters for example) and who would be able to trade the battery capacities not required in return for remuneration, provided that electricity prices are reasonable. This means that a number of electric vehicles connected to the power grid would be able to compensate for the power generation through wind or photovoltaics[1].

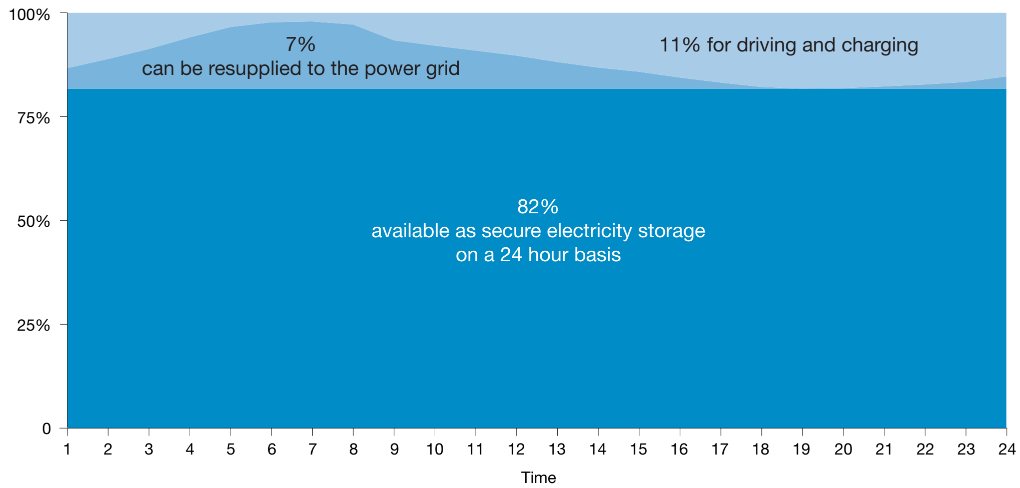
A crucial issue for the energy industry is the determination of which share of battery capacities would be available on a secured delivery basis. Secured delivery is defined as 24 hour availability (i.e. continuous supply).

Taking as a basis average traffic volumes, calculations show that 82% of battery capacities are not required during the day (vehicles are not used) and could thus be used to resupply electricity to the public power grid. A further 7% of battery capacities are used intermittently throughout the course of the day and could also be used to resupply electricity to the public power grid. Approx. 11% of battery capacities are used daily for journeys as well as for recharging.

1 Electric vehicles would thus be able to have an impact on the overall balancing of the energy market in that they could, on the one hand, resupply electricity and, on the other hand, consume additional electricity when short term excess amounts become available (for example when there is increased electricity production through wind farms).

Figure 9:
Distrubution of daily battery levels required for 'travelling' and 'charging' as well as possible resupply of non-used battery capacities

Source: PwC analysis



The table below presents the possible amounts of energy which could be resupplied to the power grid at times when electric vehicles are not being used. Assuming 20% coverage, this would mean a (secure) resupply of approx. 16 TWh of electricity to the power grid, amounting to some 17% of total electricity consumption. Assuming that 5-8% of electricity consumption (balance energy) is required for compensation energy, 20% coverage would contribute significantly to this percentage. This estimate is based on the assumption that all batteries need to be recharged. Since the existing electric vehicles would not all have their batteries charged at the same time, there would be a continuous charging process. If the total amount of battery capacities were used to resupply electricity to the power grid, the batteries would need to be recharged with the same amount of electricity.

In addition, electric vehicles would help ensure security of supply. Battery capacities could instantly be made available and, should large scale power cuts occur, could be used to resupply electricity.

The table below shows a possible resupply scenario of electricity taken from electric vehicles to the power grid for one year on the basis of an average traffic volume. Taking an average annual 2% increase in electricity production into consideration, the table also illustrates electricity consumption.

Table 4: Resupply of battery capacities to the public power grid

Annual battery capacities 20% coverage		Possible power grid supply		Secure supply amounts	
		2020	**2030**	**2020**	**2030**
Passenger cars	GWh	15,382	15,887	14,210	14,677
Light duty vehicles	GWh	1,439	1,486	1,329	1,373
Two-wheeled vehicles	GWh	158	163	146	151
Total	**GWh**	**16,979**	**17,536**	**15,686**	**16,200**
Share in electricity consumption (+2.0%)		19.3%	16.4%	17.9%	15.1%

Source: PwC analysis

A precondition for the resupply of energy would be the installation of a nationwide smart metering system which would also enable what is referred to as ‘smart pricing’; in other words the resupply of electricity on the basis of an appropriate level of remuneration. These meters would be installed within the charging stations. However, this would also mean that distribution system operators would be required to increase the capacity of electricity networks in order to ensure a greater level of data exchange.

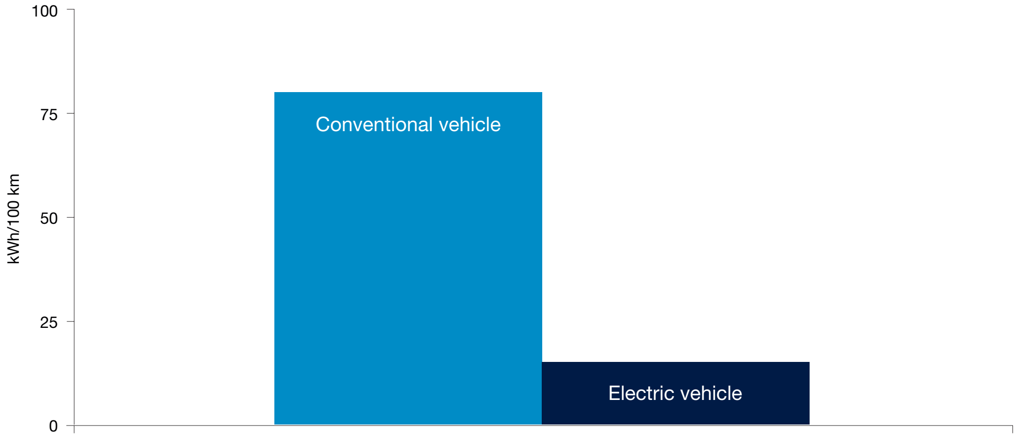
6 CO2 emissions

Electric vehicles have a higher degree of efficiency than vehicles with internal combustion engines, meaning that they are characterised by a lower average energy consumption rate[2]. Electric vehicles thus contribute towards lower CO2 emissions. It is, however, evident that the charging of batteries and the electricity produced for this purpose ultimately involves the production of further emissions.

2 Petrol and diesel in relation to cars; electricity consumption in relation to electric vehicles

Figure 10: Average energy consumption of conventional cars and electric vehicle in kWh/km

Source: PwC analysis



In order to calculate CO2 levels, the specific emission factor (how many grams of CO2 emissions are produced for 1kWh of electricity) must be determined. The CO2 calculations took the following factors into consideration:

- Planned power plant expansions of the Austrian energy industry
- Fulfilment of statutory standards regarding green electricity and renewable energy

The calculations were based on the assumption that the current power plant plans as foreseen by the Austrian energy industry until 2018 will have been implemented. It was assumed that in the period from 2018 to 2030, renewable energy sources such as hydropower and wind power will have been fully exploited. It was assumed that additional electricity capacities would be imported where further capacities are required. A general observation that can be made is that the expansion plans of the energy sector envisage a large number of fossil fuel power plants, as a consequence of which the specific emission factor related to the production of a single kWh of electricity will be have increased by 2018 compared to 2007 levels. Since the Green Electricity Act in its current form envisages that 78% of electricity will be generated through renewable energy sources by 2010, the assumption was made that the share of green electricity would remain proportionally constant until 2030.

Thus, a specific emission factor of 200 g/kWh was determined for the purpose of calculating CO_2 emissions. This amount also takes into account an electricity import share of up to 5% (corresponding to net amount[3] of electricity imports in 2007).

3 This corresponds to imports which are required for meeting domestic demand for electricity. Overall electricity imports for Austria in 2007 were above this percentage as a certain amount was also exported.

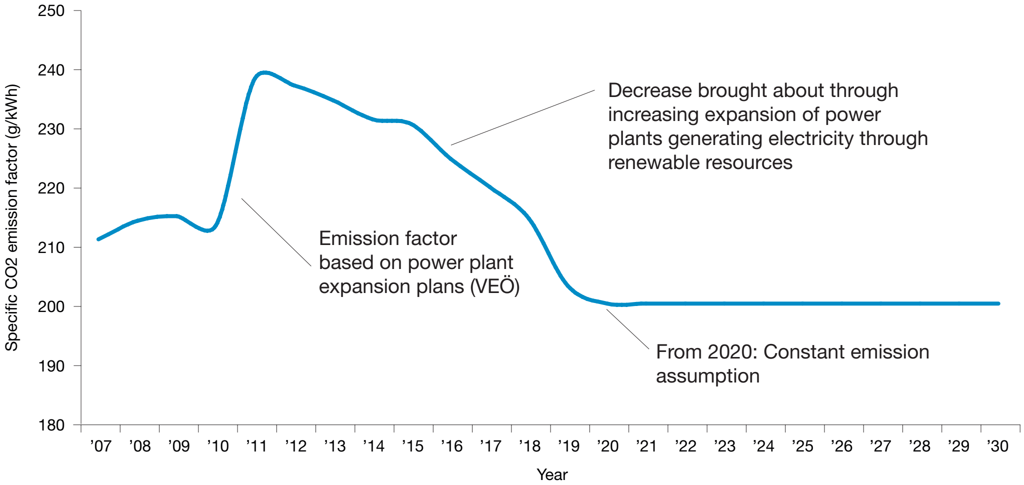


Figure 11:
Specific emission factor of electricity produced

Source: PwC analysis partially based on VEÖ data

The overall reduction made was determined based on these emission factors. Road traffic emissions (caused by passenger cars, light duty vehicles and two-wheeled vehicles) which do not take electric vehicles into account are shown in the following table[4]. Here it was assumed that by 2030 conventional vehicles will not have developed substantially in terms of efficiency. This development is due to the fact that engines will operate more efficiently while at the same becoming more powerful.

4 The CO_2 emissions comparison involving traffic here only takes into consideration those CO_2 emissions related to passenger cars, two-wheeled vehicles and light duty vehicles.

Table 5:
CO2 emissions for road traffic before and after 20% coverage

PwC analysis

CO2 emissions			
without electric vehicles	**CO2**	**2020**	**2030**
Two-wheeled vehicles	mt	0.19	0.19
Light duty vehicles	mt	1.27	1.31
Passanger vehicles	mt	11.14	11.51
Total CO2 (without electric vehicles)	**mt**	**12.60**	**13.02**
with electric vehicles		**20%**	**20%**
Two-wheeled vehicles	mt	0.15	0.15
Light duty vehicles	mt	1.02	1.05
Passanger vehicles	mt	8.91	9.20
Total CO2 (with electric vehicles)	**mt**	**10.08**	**10.41**
Reduction due to changeover	mt	2.52	2.60
Battery charging	mt	(0.53)	(0.55)
Total reduction	**mt**	**1.99**	**2.06**
CO2 reduction with electric vehicles		16%	16%

CO2 emissions can be reduced as shown in the table above. The effect is that overall emissions can be reduced by 15% when taking into account the electricity amounts used for the purpose of battery charging when using an average electricity mix in Austria.

7 Economic effects

Economic effects were assessed in the form of a cost-benefit calculation[5] and categorised as follows:

- State – impact through tax deferrals
- Imports – impact through changes in oil imports
- Consumption – impact brought about through changes in electricity an oil consumtions
- Investments – impact through investments in networks and charging stations as well as reduced investment in generation

5 In contrast to a cost-effectiveness analysis the aim here was to highlight the effects in monetary terms.

The following areas were examined:

- Additional tax revenue – VAT and energy tax
- Reduced fuel sales – Following the introduction of electric vehicles, petroleum companies will be selling less petrol and diesel. However, the crude oil for these products will still have to be imported. Once electric vehicles have been introduced, these import levels will be reduced, leading to higher levels of capital available for the national economy and therefore more capital for investments or consumption. Tax and levies were already incorporated within these calculations.
- CO2 emissions – Savings achieved through CO2 emissions and CO2 abatement costs. Emissions (CO2 in t) were valued at market value.
- Surplus arising from additional electricity sales and additional power network usage – The assumption is made that the entire electricity required for charging electric vehicles will be acquired from the public power grid. Therefore private electricity supply (acquired through solar housing, for example) were not taken into consideration. It is therefore assumed that all power requirements will have to be met by the energy industry itself.
- Reduced expansion of storage power stations – The ability to resupply the power grid with battery capacities not being used makes a reduced expansion of storage power stations possible. The assumption is made that 25% of secured energy will be able to resupply electricity to the power grid, thereby serving as electricity provider alternatives to power stations.
- Shortfalls in VAT revenue, shortfalls in fuel tax – These shortfalls are caused as a result of reduced demand for petrol and diesel, thereby affecting tax revenues. The assumption is made that the tax rate and tax base will remain unaffected-
- Expansion of battery charging stations – Necessary investments in battery charging stations; an average parameter was used. It was also assumed that home-based battery charging stations will involve the same investment costs as those situated at car parking spaces or petrol stations.

Duty payable on standard consumption (Normverbraucherausgabe) and motor vehicle insurance tax were not taken into consideration as it was assumed that once a significant number of electric vehicles would have come onto the market these would also be subject to duty payable on standard consumption and motor vehicle insurance tax and consequently would be tax neutral.

The effect on employment was not taken into consideration. While distribution grid improvements and more work caused by data processing will lead to a positive effect on the future energy job market, this will in turn have a negative impact on jobs in the crude oil sector as refinery capacities are reduced. This development would have a neutral impact on petrol stations as large heavy goods vehicles will continue to be reliable sources of income and, at the same time, petrol stations will also be able to offer electrical energy (in the form of charging adapters or charging stations)

Table 6:
Overall economic impact

Cost benefit analysis	20% coverage	
Extra earnings in EURk	**2020**	**2030**
Extra tax earnings	95,352	118,720
reduced oil imports	739,158	1,007,499
CO2 reduction	73,651	132,826
Total state/imports	**908,161**	**1,259,045**
Electricity consumption	349,527	427,280
Reduced investments in power plants	1,053,597	1,088,155
Total investments/consumption	**1,403,124**	**1,515,435**
Total national extra earnings	2,311,285	2,774,480
Shortfalls in EURk	**2020**	**2030**
Shortfalls – VAT on fuel	272,335	371,203
Shortfalls fuel duty	622,519	848,516
Total state/imports	**894,854**	**1,219,719**
Increased investment in battery charging stations	111,000	111,000
Total investments/consumption	**111,000**	**111,000**
Total national shortfalls	1,005,854	1,330,719
Overall economic impact	**1,305,430**	**1,443,762**
Share tax and duty	13,307	39,326
Share consumption/investments	1,292,124	1,404,435

The above table shows a considerable number of tax deferrals, reduced oil import dependency and, as a consequence, a reduction in capital which remains in Austria as well as significant extra earnings through additional electricity sales. The ability to resupply electricity with battery capacities not being used (through parked electric vehicles) would also result in a reduced need to expand power stations, thereby leading to reduced investment.

The overall economic impact generally paints a positive picture, with the effect on the national budget being largely neutral (slightly negative in 2020 and slightly positive in 2030). The most positive effect will be felt by energy suppliers, which will hugely benefit through a positive net effect of up to around EUR 1.3bn.

8 Possible contribution towards meeting energy efficiency targets

The EU Directive 2006/32/EC (Energy Service Directive – ESD) envisages a 9% increase in energy efficiency as an interim target by 31 December 2016 and an overall 20% reduction in primary energy carriers by 2020. For Austria, such a target would imply a demonstrable energy reduction of 80,400 TJ (22,333 GWh) compared to a reference scenario. The reduction level was determined as part of a national allocation plan for energy efficiency (source: EEAP, BMWA, 2007).

The following table shows the results of the study into the possible contribution that electric vehicles could make towards achieving energy efficiency targets:

Table 7:
Contribution of electric vehicles towards achieving energy efficiency targets

	20%	
Petrol and Diesel usage (GWh)	**2020**	**2030**
Petrol cars	4,882	5,042
Diesel cars	5,272	5,445
Two-wheeled vehicles	181	187
Light duty vehicles	688	710
Total	**11,023**	**11,384**

	20%	
Charging energy for electric vehicles (GWh)	**20%**	**20%**
Cars	2,400	2,478
Light duty vehicles	224	232
Two-wheeled vehicles	25	25
Total electric cars	**2,649**	**2,736**
Reduction/Saving	8,374	8,649
Targets	**37%**	**39%**

Source: PwC analysis

The results show that on the basis of 20% coverage (amounting to approx. 1 million vehicles), the contribution that can be made in terms of meeting energy efficiency targets amounts to 37% or 8.4 TWh of the 22.3 TWh target. This would be capable of having a net effect on the economy of up to approx. EUR 1.3 billion.

Your contacts at PricewaterhouseCoopers

Your contacts for the survey

Bernhard Haider
Partner
Tel. +43 1 501 88 2900
bernhard.haider@at.pwc.com

Erwin Smole
Director
Tel. +43 1 501 88 2928
erwin.smole@at.pwc.com

www.pwc.at