Balancing power grids with electric vehicles

*By **Wolfgang Ketter and Jan van Dalen***

In the days when most of our electricity needs were covered by centralised fossil fuel power stations, output and demand could relatively easily be predicted and balanced. But with an ever greater supply now coming from less predictable and controllable sources such as wind and solar energy, grid balancing has become more difficult. Using the battery capacity of electric vehicles as a source for virtual power plants could be a solution. It can also make money for a vehicle's owner.

With the trend today moving away from top-down vertically integrated fossil fuel generation towards decentralised electricity sources, certain factors are no longer within a power plant operator's control. The operator cannot predict with any high degree of accuracy how hard the wind will blow or how long the sun will shine, and there could be large fluctuations in generating capacity. In times when renewable output is low, back-up fossil fuel plants have to be brought into use to make up the shortfall. At other times when output is high, wind farms might have to be taken offline to avoid overloading the grid, which is both wasteful and inefficient.

EVs to the rescue?

Our research (*Electric Vehicle Virtual Power Plant Dilemma: Grid Balancing Versus Customer Mobility*) shows that using electric vehicles (EVs) as virtual power plants (VPPs) can play a crucial role in balancing smart electricity grids, thereby addressing these key issues.

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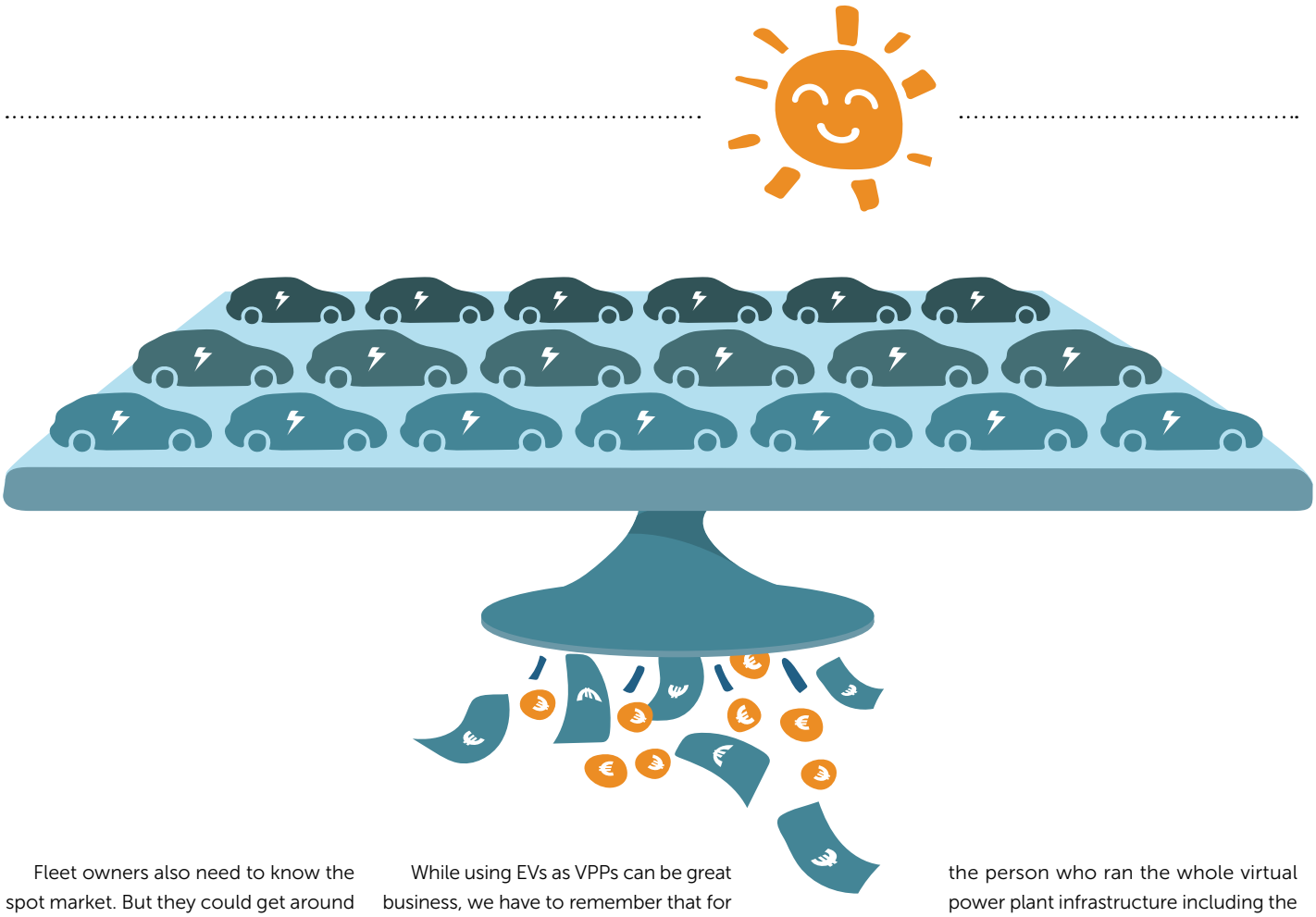
While individual drivers can make a difference, the impact will be much greater at scale. For this reason we focused our study on the management of EV fleets organised as VPPs, and analysed the potential of parked vehicles to absorb excess electricity from the grid when energy supply is high and demand elsewhere low, and to feed electricity back into the grid by discharging when supply is low and demand high.

What we found was that such VPPs can be both ecologically advantageous, through reductions in wind power curtailment, and beneficial to consumers by reducing energy expenses. Crucially, however, they can also be profitable for fleet owners, by charging cars when low demand drives spot electricity prices down, and selling the same power back to the grid at times when high demand drives prices up.

Challenges ahead

But while this may sound like a licence to print money, there are a number of specific challenges that must be addressed if we are to make the best use of electric vehicles in this way. One big issue is infrastructure. We need charging stations to be located where there is highest demand for EVs, as these stations form a critical element of the whole virtual power plant. The location might be city dependent, environment dependent, or even seasonally dependent, but it requires careful planning. And of course, the charging points need to be bidirectional so that they can not only charge but also discharge a battery.

Then there is a large-scale prediction problem. In order to make the most of the situation an EV fleet owner would ideally need to know when the sun will shine or when the wind will blow the most, to take the best advantage of spot price fluctuations in the market. In other words, they need to be able to plan intelligently.



Fleet owners also need to know the spot market. But they could get around this by going to an external trading company. This might cut the profit margin down as they would have to pay a commission to the third party, but they still make money.

The mobility of people is perhaps the most important issue that must be factored in. After all, the first part of the business case for any EV fleet, whether it is for rental to individuals or use by a single company, is to move people around. We should not inconvenience them simply to provide a power source. A fleet owner therefore needs to know when and where there will be high demand for cars so that they can make those cars available.

While using EVs as VPPs can be great business, we have to remember that for the fleet manager it is only a side business. Nevertheless, a well-managed fleet can become something we call "doing well by doing good". The fleet owner is doing good by providing a service to society: changing high volatility in the grid to a high level of energy independence to create balancing capacity. But at the same time, they are doing well for their company's pocket by creating a second business model with an alternative income stream.

Behavioural change

In the cases we studied, the fleet owner (Car2Go in San Diego, Amsterdam, Copenhagen and Stuttgart) was also the person who ran the whole virtual power plant infrastructure including the charging stations, but that doesn't have to be the case. It can vary in different environments. The important thing is that the two halves come together at the right times.

This means an element of behavioural change is required on the part of the EV user. In the cases we studied there was no incentive for the drivers to park the cars after use near to one of the charging stations. To benefit fully, that behavioural aspect needs to be in place – you want to have the cars available for usage, but also for discharging. They need to be parked and connected to the grid at the right time; otherwise they cannot take advantage of energy trading.

One unique property of this mixed usage trading strategy is therefore that decisions have to be made between making an EV available for use, where the location within the city matters – drivers want cars to be near their place of departure or arrival – and discharging it to the grid. In the latter case location matters less, as vehicles can discharge from any capable charging point, wherever it is. It is a balancing act in which incentives may help, such as providing free driving minutes to encourage drivers quite literally to go the extra mile to seek out charging points.

Geography matters

Local factors are also important, and have a direct impact on the EV fleet's potential use as VPPs. Physical properties and culture both play a big role, as the different cases that we explored. The results were dependent not only on the country, but also on the individual city. In Germany there is a high penetration of sustainable resources. In Stuttgart we saw a high uptake of EVs and you can also make good profit there. All cities we looked at show an annual profit increase, but Amsterdam appears to benefit the most.

Huge potential

This geographical diversity, both in terms of the ability to generate renewable power and the cultural acceptance of the concept, means there is no easy one-size-fits-all solution. But to make the scenario of using electric vehicles as grid-balancing virtual power plants attractive, providing economic benefit without unnecessary inconvenience the success of a VPP depends on what percentage of sustainable resources a location has in its energy mix, and on the rate of energy taxes. It is also dependent on the willingness of people to share vehicles – this is much higher in Europe generally than it is in the United States.

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What we discovered was that there was very different usage of cars between is the main selling point. If the fleet owner can provide a service for society while still making a profit, it will be a win-win situation in keeping with the UN's Sustainable Development Goals: generating income and providing green power when needed.

As the vast bulk of most cars' time is spent parked, turning them into virtual power plants during idle periods could have a massive impact both on society and the bottom line. And with some predictions suggesting there could be one billion EVs on our roads by 2050, as falling battery costs make them cheaper to produce and improved performance makes them more attractive to owners, the potential rewards are vast. ■

To see the potential benefits of electric vehicles as virtual power plants yourself, visit our Power TAC website (www.powertac.org). This is the world's largest free, open-source smart grid platform, which you can use to test this and a range of other sustainability scenarios.

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