Policy Brief: EU Power Policies for PEVs[1]

Accelerating from here to en masse

PEVs Could Offer Significant Benefits

Plug-in electric vehicles (PEVs) offer substantial potential benefits to urban well-being. PEVs have no tailpipe emissions[2] and create far less noise compared with conventional vehicles. The European Commission's Transport White Paper[3] sets out to capture these benefits by establishing benchmarks that serve to halve the use of conventionally fuelled cars in urban transport by 2030 and phasing conventional vehicles out in cities by 2050. With the EU power sector progressing towards the European Commission's EU Energy 2050 roadmap's[4] goal of 96-99 percent carbon reduction by 2050, PEVs also have the potential to reduce the EU's dependency on oil and to decarbonise the passenger car fleet in the longer term.

How and when PEVs are recharged can dramatically affect the electric grid in different ways.[5] Negative effects could include increased peak loads, over-stressed local distribution networks, and increased air pollution from electricity generation. Whereas, the potential benefits to the grid could include greater use of base load capacity during off-peak periods (load smoothing) and cheaper ancillary grid services. PEVs could also help to integrate variable renewable energy sources (RES).

Increasing shares of variable RES entering the electricity system mean that the resulting net energy demand profile (i.e. total energy demand minus the available low marginal-cost renewable energy from resources such as wind and solar) will become increasingly variable and more challenging to balance. The current focus on peak demand in relation to total system capacity will yield to the more pressing concerns associated with operational reliability and net demand. This is where the system can best capture the value from PEVs. The ability of PEV batteries coupled with the flexible way in which they can be recharged - able to stop, start, accelerate, or decelerate with very high ramp rates, or provide a constant rate of recharge – provides a very flexible energy resource that is able to integrate variable RES into the electricity system.

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[2] Air pollution due to a switch from conventional vehicles to PEVs would be controlled by EU legislation, in particular the National Emissions Ceilings Directive, the Air Quality Framework Directive, and the Industrial Emissions Directive. See: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm

[3] European Commission. (March, 2011). Roadmap to a single European transport area – towards a competitive and resource-efficient transport system. COM (2011) 144.

[4] European Commission. (December, 2011). Energy 2050 Roadmap. COM (2011) 885.

[5] See: MJ Bradley & Associates. (forthcoming July 2013). Electric Vehicle Integration in the US, Europe and China: Challenges and Choices for Electricity and Transportation Policy. Montpelier, VT: Regulatory Assistance Project.

Power Sector Regulation Will Influence Rate of PEV Roll Out

Despite the promise of PEVs toward meeting environmental and security objectives, PEV sales in Europe have been lower than expected. Several factors explain this, including the following: the cost of PEV ownership, particularly the purchase price, compared to a similar car powered by an internal combustion engine (ICE) remains high; vehicle recharging time can be long at the more common lower-voltage levels; availability of public recharging infrastructure is limited; and the distance range of a fully charged battery is considerably less compared with a full tank of gasoline or diesel. Improvements in PEV technologies, as well as customer acceptance and adaptation will be important in overcoming these barriers but regulation of the power sector could have a significant influence on the rate of PEV roll out.

How regulators think about integrating PEVs into the grid is framed in the context of European legislation driving towards full energy market integration and decarbonisation. With this in mind, the following three core objectives should shape how regulators prepare the power sector in order to ensure that mass roll out of electric vehicles is facilitated and not hampered:

1. **Minimise negative grid impacts.** Potential negative impacts include increased peak load, overstressed distribution networks, and increased emissions from generation.
2. **Maximise grid benefits.** Potential benefits include the provision of very flexible ancillary services/reserves[6] that help reduce curtailment of variable renewable energy and increase utilisation of the grid.
3. **Shrink the total ownership cost gap between PEVs and ICE vehicles.** Total ownership costs include primarily the vehicle purchase price, plus the cost of electricity for fuelling and the value that PEVs can extract from the electricity system.

This policy brief sets out power sector policies and regulation that can facilitate or promote PEV roll out with a focus on the following key areas: the role and design of time-varying electricity pricing; adaptation of EU electricity market rules to enable demand response;[7] and the character of regulation that will likely be needed to encourage distribution system operators (DSOs) to be effective contributing partners in advancing progress with the roll-out of PEVs.

PEV Recharging Will Need to be Managed From the Outset

The highest risk to the overload of the grid in the near term due to PEV recharging will be at the distribution level. As recharging a PEV at home will increase the load of the average EU household significantly by just over 50 percent,[8] simultaneous and uncontrolled[9] recharging of PEVs on the same

[6] Ancillary services describe the various balancing tools and reserves that system operators rely upon to maintain operational stability of the power system. In Europe, these services are often referred to as primary, secondary, and tertiary reserves.
[7] Demand response involves end users reducing their electricity consumption in response to economic signals, such as competitive wholesale market prices or retail rates, which reflect the needs of the electricity system.
[8] MJ Bradley & Associates. (forthcoming July 2013). Electric Vehicle Integration in the US, Europe and China: Challenges and Choices for Electricity and Transportation Policy. Montpelier, VT: Regulatory Assistance Project.

distribution circuit risks overloading transformers. Uncontrolled recharging of PEVs also risks an increase in system peak demand which would not only threaten reliability but could also result in higher clearing prices in wholesale electricity markets and higher greenhouse gas and toxic air emissions if the marginal generation is fossil-fuelled.

Encouraging customers to shift PEV recharging to off-peak periods, even at very low PEV penetration levels,[10] will help mitigate risks to power reliability and reduce the need for construction of new generation and additional transmission and distribution capacity. Recharging in times of low net demand when the combined output of variable RES (particularly wind and solar) and inflexible baseload plant such as nuclear might otherwise need to be curtailed, will help integrate these zero and low carbon resources.

Because cars are usually parked for long periods of time at home or at work there is a long timeframe over which recharging can take place and during which time ancillary services can be provided to the grid. Vehicles across the EU tend to be driven actively for less than two hours per day. The rest of the time they are either "actively" parked in the intervals between trips, or "inactively" parked, typically during the work day, or overnight.[11] The manner in which that recharging is undertaken does not matter to the PEV owner so long as the battery is recharged to a certain level, by a certain time, and without negative impact on the battery.

'Normal' recharging (Mode 1 (4kW)) will be the default recharging method in Europe largely because existing electricity infrastructure is adequate, delivering 220-240V, to enable full recharge overnight or while at work. Normal recharging also has greater potential than 'fast' recharging (Mode 2 (20kW) or Mode 3 (40kW)), which requires installation of expensive infrastructure,[12] to offer ancillary services to the grid which are necessary to integrate growing shares of variable RES. In addition, fast recharging has much greater potential than normal charging to stress the network, the vehicle on-board charging circuitry, and the batteries.[13]

PEVs Can Provide Valuable Services to the Electricity System

The compensation for services that PEVs can provide to the electricity system will depend on factors such as market design, system operator (DSO/TSO) regulation, transaction costs, and the intersection of

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[9] Uncontrolled charging exists when charging is controlled by the consumer and electricity prices reveal little or no information.

[10] Of particular relevance where clustering of PEVs on the same distribution circuit occurs and where distribution networks are weak.

[11] G. Pasaglou et al. (2012). Driving and parking patterns of European car drivers - a mobility survey. European Commission Joint Research Centre.

[12] Mode 2 estimated to cost €39,700 capital and €4,000/year operations and maintenance. Mode 3 €59,800 capital and €1,000/year operations and maintenance. See: Schoeder, A. and T. Traber. (2012). The economics of fast charging infrastructure for electric vehicles. *Energy Policy* 43: 136–144.

[13] See: MJ Bradley & Associates. (forthcoming July 2013). Electric Vehicle Integration in the US, Europe and China: Challenges and Choices for Electricity and Transportation Policy. Montpelier, VT: Regulatory Assistance Project.

the market's supply and demand curves. Important to the business model will be whether PEVs can provide the services more cheaply than competing alternatives including conventional generation or other distributed loads, such as residential electric hot water heaters.

A recent study commissioned by the European Climate Foundation estimates that the value that the PEV fleet can provide to the grid[14] will be a significant proportion of the annual electricity refuelling cost. The study modelled three unidirectional grid-to-vehicle (G2V) services: "one-way" frequency response/primary reserve (short duration), "one-way" secondary reserve (longer duration), and energy storage to reduce curtailment of renewable energy output. In this study, the total value of the three services was estimated to be €160/annum in 2020, with value split fairly evenly between the three services. This value is predicted to reduce over time to €100/annum by 2050, as the value of frequency response per participant reduces significantly with market saturation. By contrast, the value of reduced RES curtailment and reserves stays fairly constant to 2050 such that electricity refuelling costs in 2050 can be offset by 50 percent. Early adopters can benefit from the high value of frequency response.

Over time, PEVs might also be able to discharge power to the grid if technical and economic barriers are overcome. Bidirectional charging involves two-way power flow where vehicles are able to discharge electricity to the grid. Bidirectional charging would enable pooled PEVs to operate as a virtual power plant and grid reinforcements to be avoided up to very high PEV penetration rates.[15] Compared with unidirectional charging, bidirectional charging would expand the flexible grid services that PEVs could offer, particularly the types of reserves (discussed below) and storage needed to integrate variable RES. Storage provided through bidirectional charging could be compensated through arbitrage where batteries are charged when wholesale electricity market prices are low and discharged when prices are high.

The economic feasibility of bidirectional charging, however, is uncertain, continues to be debated in the industry, and is the subject of considerable research and demonstration around the world.[16] The increased two-way cycling results in battery wear such that bidirectional charging is only feasible if the cost of the battery and the vehicle based bidirectional power interface required to enable discharge to the grid can be adequately financially compensated. Furthermore, if the battery is to provide

[14] European Climate Foundation (2013). Fuelling Europe's Future: How auto innovation leads to EU jobs. Retrieved from http://www.camecon.com/Europe/EnergyEnvironment/FuellingEuropesFuture.aspx. The study assumed 80 percent RES by 2050. For response and reserve, the value of capacity and utilisation are based on historical data provided by the UK National Grid. Reserve valuation is €41k/MW.annum and response valuation is €66k/MW.annum (reducing over time per MW of total EV storage as the fleet grows in size and saturates the response requirement). The value per unit of PEV storage capacity is calculated at €90-110/kW.

[15] G4V Project. (September, 2011). System analysis and definition of the roadmap: D7.2 Description of the analytic concept/model of G4V impacts and exigencies including derived recommendations for necessary regulatory and technological developments (Roadmap). Retrieved from http://www.g4v.eu/datas/reports/G4V_WP7_D7_2_roadmap.pdf.

[16] For example, conclusions of the G4V project (www.g4v.eu) state that bidirectional charging is not a profitable business concept yet and that charging strategies should be further analysed and reconsidered for a large penetration of PEVs.

measurable power to the grid at a predictable time of day, there is a risk, which is higher during the day than at night as this is when most people need their vehicles, that this might compromise the vehicle's useful range when the owner needs it.[17] **While bidirectional charging may become feasible in the future, unidirectional charging strategies to deliver grid services through postponement or interruption of recharging, for which the EV owner can be compensated (including "one-way" frequency response, "one-way" reserves, and reduced curtailment of variable RES) can be promoted immediately at little additional cost to vehicle owners.[18] This policy brief therefore focuses on the value to the grid of unidirectional recharging.**

Voluntary Response to Pricing May Not Deliver Full PEV Value to Grid

Advanced forms of time-varying pricing (i.e., dynamic pricing) can encourage off-peak recharging. However, there is substantial evidence in other contexts that Time of Use (TOU) pricing has limited effects on customer behaviour unless the rate differentials are very high. People might be more responsive, however, to pricing for recharging of PEVs compared to other household loads. Early results from the EV Project[19] in the US suggest this is so. Ahead of rolling out such rates, well designed pilots can be carried out to assess how responsive PEV owners will be.[20]

Simpler forms of time-varying pricing, combined with use of a smart charger[21] to automate response, can be used to some good effect in the early stages of PEV deployment. These simpler forms would likely come through some form of voluntary off-peak charging in response to pre-determined TOU tariffs, which are tiered to indicate to the PEV owner when or when not to charge. For example, in France, EDF offers customers an electricity pricing option that has lower rates during off-peak hours[22] and in the UK, E.On offers TOU rates (called Economy 7).[23]

However, over time, well-designed TOU rate design can lead to new local peaks with dramatically negative impacts on the local grid.[24] Pricing with a dynamic component (e.g. real-time pricing (RTP)), again combined with use of a smart charger to automate response, can help address simultaneous

[17] Morgan, T. (February, 2012). Smart Grid and Electric Vehicles: Made for Each Other? International Transport Forum. Retrieved from http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201202.pdf.

[18] Compensating vehicle owners for ancillary services would require a separate meter to be installed.

[19] For more information see: http://www.theevproject.com/

[20] For further information on time-varying rate design and design of pilot studies see: Faruqui, et al. (July 2012). Time-Varying and Dynamic Rate Design. Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/5131.

[21] A smart charger may simply be an electronic device with an ability to communicate with the aggregator. This requires no grid upgrades at all. See http://phys.org/news160304599.html and http://techportal.eere.energy.gov/technology.do/techID=1047.

[22] See EDF website: http://particuliers.edf.com/offres-d-energie/electricite-47378.html.

[23] See E.On website: http://www.eonenergy.com/for-your-home/help-and-support/metering.

[24] G4V Project. (June, 2011). Analysis of impacts and opportunities in power system Operation: D6.2 estimation of innovative operational processes and grid management for the integration of EV. Retrieved from http://www.g4v.eu/datas/reports/G4V_WP6_D6_2_grid_management.pdf.

charging and can generally elicit response more successfully than TOU rates alone. Time-varying pricing where PEV owners are responsible for controlling recharging, even if using automation technologies and where pricing has a real time component, does not generally deliver dispatchable energy resources to the system that the system operator (DSO or TSO) can rely upon. **Thus, the capability of time-varying pricing to integrate variable RES is limited.[25] Active management and balancing of the distribution networks, for a generation mix with high shares of variable RES and distributed energy resources (DER), will require remotely dispatchable energy resources.**

Even if the PEV owner would enter into a contract to deliver dispatchable demand response, the PEV owner would not likely be able to **participate in electricity markets. The latter is enabled through aggregation** where an aggregator combines energy related services from different sources (end-user loads or distributed generators) and interacts with the grid operator as a single entity. An aggregator would respond to real time price signals from the DSO or TSO and communicate with the PEV's onboard computer to dispatch recharging using sophisticated communication and control technology. The customer would permit the aggregator to control how and when recharging takes place in accordance with pre-agreed constraints (and with an opportunity to override when needed by the customer).[26]

Regulation to Fully Capture PEV Value to the Electricity System

In the future, capturing the value of PEVs to the grid would not only bring benefits to the electricity system and all electricity consumers, but could also significantly reduce or offset the total cost of PEV ownership and improve PEV competitiveness relative to ICEs. **In order that the value of these benefits might be fully captured, regulators will need to ensure that:**

a. Demand response and aggregators can fully participate in markets;
b. Various critical modes of resource flexibility are fairly and fully priced or compensated in electricity markets;
c. Distribution networks are able to effectively and efficiently support the operations of aggregators;
d. Emerging business models provided by any service provider that may facilitate new services are not unduly hampered by regulatory, administrative, or market barriers; and
e. Appropriate standardisation for interoperability of key infrastructure across the EU is not delayed.

a. Ensure that Demand Response and Aggregators Can Fully Participate in Markets

Market adaptation will need to begin early in order to enable effective participation of demand response in electricity markets. After all, it will take time for responsive demand-side services to emerge even after the markets permit them. Growth in the demand for these services will inevitably increase

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[25] Cappers, P. et al. (October 2011). Mass Market Demand Response and Variable Generation Integration Issues: A Scoping Study. Berkeley, CA: Lawrence Berkeley National Laboratory.

[26] As aggregators will be contractually accountable to the system operator (DSO/TSO) for delivering services, they may be required to pay penalties to the system operator for non-delivery of services. Aggregators may need to pass on part of these penalty payments to customers who choose to override the aggregators' control signal. How penalties are calculated and applied would need to be clearly explained in the customer's contract.

with increasing shares of RES entering the system. **A priority action for regulators will be to remove or minimise any existing regulatory or market barriers that prevent demand response participating in electricity markets on a comparable basis to generation. Some of these barriers are listed below:**

- Minimum bid requirements that are too large or onerous to permit the participation of new entry and end-user loads or their aggregators;
- Failure to adequately compensate for all valued services delivered;
- Rules that do not differentiate, and therefore adequately recognise the full value of, frequency response "up" and "down" as distinct products;[27]
- Unwarranted site or location restrictions that bear no relation to the value of services provided to the system;
- Unnecessarily long length of forward commitment; and
- Unreasonable availability requirements or penalties relative to supply-side resources and for individual loads or service providers when the performance of the aggregate is most relevant.

US experience shows that, in addition to removal of such barriers, stable and adequate revenues for demand response providers are key to ensuring demand-side participation.[28] Demand response has flourished in electricity markets (wholesale electricity, ancillary services, and capacity) in the US largely because the Federal Energy Regulatory Commission (FERC) has ensured that the necessary policy and regulatory framework enables demand response to be compensated in a manner comparable to generation resources and, where applicable, for the faster and more precise response it is able to provide.

More recently, the application of demand response in US markets is broadening to help integrate DER and RES. For example, Enbala is using distributed loads and storage to provide ancillary services, including frequency regulation and regulating reserve[29] in US markets.[30] Pilot programs in Europe are demonstrating that PEVs can help to better integrate wind resources.[31]

b. Ensure that Various Critical Modes of Resource Flexibility Are Fairly and Fully Valued in Markets

The increasing share of renewable generation in the generation mix will affect the type of ancillary services or reserves required to both ensure system reliability and needed power quality. Some studies indicate that requirements for the shortest-duration (primary) reserves are not significantly impacted by

[27] Unidirectional charging provides "one-way" services/reserves whereas bidirectioncal charging can provide "two-way" services/reserves.

[28] Hurley, D., Peterson, P., and Whited, M. (March, 2013). Demand Response as a Power System Resource: Program Designs, Performance, and Lessons Learned in the United States. Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/6597.

[29] In EU electricity reserves/services markets, frequency regulation (also known as frequency response) is equivalent to primary reserves and regulating reserves are equivalent to secondary reserves.

[30] For more information, see: http://www.enbala.com/SOLUTIONS.php?sub=Distribution-Scale.

[31] See the Edison project website (http://www.edison-net.dk/) and the EcoGrid EU demonstration project (http://www.eu-ecogrid.net/).

higher shares of variable energy renewables. Rather, the type of services needed to integrate growing shares of variable generation for renewable sources will likely be:[32]

- "flex" option–the ability to shut down and re-start, or cycle, a resource multiple times within a reasonably short window of time and up to hundreds of times over the course of the year;
- "dispatch" option–the ability to reduce a resource to a low level of stable operation and ramp it back up at a specified rate, not in a traditional operating reserve role but as a normal-course ramping capability; and,
- secondary reserves for regulation and load-following to address issues arising in the tens of minutes (e.g., forecasting error).

These services will be needed on a daily basis through all seasons of the year and would best be delivered by loads which consume considerable amounts of energy, especially those that have access to some kind of storage, where the load can be interrupted for periods of time or shifted a few hours without degrading the delivery of the energy service. Demand response, including PEVs, can contribute to proving these flexible services and will likely offer a more cost-effective alternative to fossil fuelled plant in doing so.[33]

To be sure that investments are made in the right type of energy resources most needed by the system, compensation will need to parallel compensation mechanisms for the underlying firm (i.e., guaranteed) capacity. The methods for determining compensation in reserves markets and in capacity markets, where they exist, will significantly affect whether PEVs or other forms of demand response can provide these services. In the US, FERC recognised that resources providing such services differ in their ramping ability and the accuracy of their response and that compensation by system operators did not account for such differences. In 2011, concluding that rates were unjust, FERC introduced Order No. 755 requiring system operators to base payment in part on the valued performance characteristics of each resource.

Options to adapt markets to more fairly value resource performance, including flexibility, could include adapting the **short-term ancillary services market.**[34] **These markets could be expanded or adapted to include new services or products as necessary**. Including new services or flexible characteristics that are valued will fundamentally expand the participation of the demand side. And where they exist, **forward capacity markets could be adapted by breaking the total quantity of firm resources required into successive tranches based on specified resource attributes** with consideration for the ramping, cycling, and rapid response capabilities that may be needed with growing shares of variable RES entering the

[32] Hogan, M. and Gottstein, M. (August, 2012). What Lies 'Beyond Capacity Markets'? Delivering Least-Cost Reliability Under the New Resource Paradigm. Montpelier, VT: Regulatory Assistance Project. Available at http://www.raponline.org/document/download/id/6041.

[33] North American Electric Reliability Council. (2009). Accommodating high levels of variable generation. Princeton, NJ: North American Electric Reliability Council. Available at http://www.nerc.com/files/IVGTF_Report_041609.pdf.

[34] Hogan, M. and Gottstein, M. (August, 2012). What Lies 'Beyond Capacity Markets'? Delivering Least-Cost Reliability Under the New Resource Paradigm. Montpelier, VT: Regulatory Assistance Project. Available at http://www.raponline.org/document/download/id/6041.

system. Such market design change could significantly improve the business models of aggregators and the extent to which the cost of PEV ownership can be offset in the future.

c. Ensure Distribution Networks Are Able to Effectively and Efficiently Support the Operations of Aggregators

New loads, such as PEVs and heat pumps, along with the need to upgrade and smarten the grid to integrate DER and large-scale RES, will likely increase the capital expenditure of DSOs in the future. With the massive deployment of distributed generation and increasing demand side participation, the DSO's role will change with new tasks and greater interaction with market actors and TSOs. The DSO will need to manage power flow effectively in both directions, keep the distribution system balanced, manage congestion, losses and power quality, and at the same time act as a market facilitator. With the DSO playing an increasing role in balancing the system at local level, **greater coordination and cooperation between DSOs and TSOs will be needed. The regulator will need to consider redefining their roles and interface to ensure efficient coordination.**

Further, the DSO's more dynamic and active role implies operating expenditure will also increase. Meanwhile, energy efficiency alongside the integration of more distributed generation, demand, and storage, will reduce the energy that needs to be distributed or transmitted and so result in reduced revenues. **At the same time, efficient operations, facilitated by smart grid technology, can achieve savings particularly if grid upgrade or build-out is prevented. The cost recovery regulatory mechanism should therefore ensure fair cost recovery but also incentivise efficiency on a long term basis.**

An alternative to traditional cost-of-service regulation is performance-based regulation (PBR). A PBR framework can be either price-based or revenue-based. A price-based framework is generally recognised as linking the regulated entity's financial performance to growth in sales. This can be a problem for promoting certain categories of investments in clean energy, including energy efficiency and customer-side generation. **A revenue-based framework (either focused on gross revenues or revenues-per-customer) helps ensure that the alignment between sales growth and the DSO financial performance is broken.**

But even while revenue-based PBR may break the link between sales growth and financial performance, it still maintains the critically important incentive to manage costs. The associated risk however is that without explicit performance requirements and an associated framework of penalties and rewards, service quality and system performance might be compromised in the process.

Additionally, **the PBR framework can link DSO performance to achievement of certain public policy goals.** Well-designed PBR replaces existing disincentives with rewards for superior performance in achieving defined goals, for example: improving reliability; delivery of PEV recharging infrastructure; cost-effective procurement of balancing and congestion management services; distribution infrastructure to support DER, including PEVs; and innovating to cut costs and deliver services. **The indicators to assess achievement of PBR goals need to be measurable and controllable by the DSO.**

It is the responsibility of the national regulator to regulate DSO revenues, grid tariffs, and access to the network. National regulators can incentivise or require DSOs to use time and location-based pricing signals (tariffs). Such tariffs could encourage aggregators of retail customers, retail suppliers, or other parties to deliver grid support services that ensure best use is made of available network capacity and distributed energy resources–including variable RES, storage, and load–in order to effectively manage network congestion, reliability, and power quality. However, location-based pricing runs considerable risk of provoking customer dissatisfaction. An alternative may be targeted credits and incentives that appropriately compensate consumers, helping to avoid system upgrades where the costs are ultimately shared by all customers within the DSO territory in future rates. **Incentives as part of tailored or 'smart' contracts could give DSOs more flexibility and be easier to implement than system-wide locational and temporal network pricing.[35] Regulation could be adapted to allow or even incentivise the use of contracts and incentives or credits.**

d. Ensure That Emerging Business Models Are Not Hampered By Regulatory, Administrative or Market Barriers

Aggregators can be expected to coordinate closely with customers, DSOs, and TSOs to extract the greatest value to the grid of their pooled resources, including PEVs and other dispatchable loads. At times, however, aggregators may appear to face competing demands from DSOs and TSOs. In addition, new business models may emerge bringing new entrants and more opportunities to improve the flexibility performance of the demand-side to electricity markets.

Business models that provide a profit or benefit at every step in the value chain are more likely to be successful. The purchase package needs to be financially attractive for PEV owners and kept reasonably simple. Business models might bundle services from several market actors in the value chain in ways that complement the interests of all. For example, PEV manufacturers, perhaps working with other electricity market actors, or functioning as an aggregator of retail customer EV loads, could bundle the purchase price of a vehicle with an initial or monthly credit for relinquishing some measure of remote control over the vehicle battery. That value of the credit given to the customer could then be recovered from the services derived and delivered to system operators (i.e., the TSO or DSO).

The Agency for the Cooperation of Energy Regulators (ACER) and Council of European Energy Regulators (CEER) believe that competition in the electricity retail sector needs improving given the low switching rates between retailers.[36] A competitive and liquid cross-border retail market that allows easy access for new and small entrants will be very important to unlocking the value that PEVs can provide to the grid. Tariffs should also be as simple and transparent as possible.

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[35] Brandstatt, C., Brunekfreeft, G., and Friedrichsen, N. (September, 2011). Improving investment coordination in electricity networks through smart contracts. Bremen, Germany: Bremer Energie Institut. Retrieved from http://www.bremer-energie-institut.de/download/bewp/bewp10.pdf.

[36] ACER/CEER. (November, 2012). Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2011. Luxembourg: Publications Office of the European Union. Retrieved from http://www.acer.europa.eu/Official_documents/Publications/Documents/ACER%20Market%20Monitoring%20Report.pdf.

Given that the DSO will increasingly interact with market actors and that it also has access to and manages commercially sensitive information, **regulators at the EU and Member State level may need to consider further unbundling of DSOs.**[37]

A regulatory priority will be to ensure that DER, demand response, and aggregators can compete on comparable terms to generation in provision of services to either DSOs or TSOs, and that new entrants are not unnecessarily restricted by requirements that only large, established companies or supply-side resources could realistically comply with.

e. Ensure Appropriate Standardisation For Interoperability of Key Infrastructure Across the EU is Not Delayed

The adoption and harmonisation of technical standards are critical to the roll-out of PEV technology including related recharging infrastructure. Standards ensure interoperability and avoidance of higher costs from divergent national approaches. While the European Commission and standardisation bodies continue to make progress in this area, it is important that standardisation processes are not delayed and that such standards are forward-looking and designed to achieve objectives. Standards should also attempt to reduce the risk of lock-in or redundant technology**. Importantly, standards should not foreclose options for PEVs to participate in more advanced forms of demand response and energy storage programs that directly link to advanced forms of dynamic pricing and markets for needed services from these potentially valuable end-user loads.**

Regulating to Keep the Pressure Down on Electricity Prices

In the meantime, while demand response and aggregators establish themselves in markets, regulators can further close the cost of ownership gap through regulatory action, which will have a downward effect on electricity prices. Full implementation of the internal energy market and Target Model[38] will help reduce electricity prices through, for example:

- Financial and physical pooling/joining up of electricity markets such that trading of all types of electricity at all timescales across all Member States is possible;
- Optimal interconnection across the EU; and
- Full unbundling and establishment of competitive and liquid electricity generation and retail markets.

Aggressive system-wide energy efficiency and the enabling of full participation of demand response in electricity markets will reduce the clearing price in wholesale electricity markets and provide consumers, including PEV owners, with cheaper electricity.

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[37] While unbundling of networks has been implemented across the EU27 as part of the Third Energy package legislation, full ownership unbundling has not been required, and Member States (MS) have tended to opt for legal unbundling of vertically integrated electricity companies. Exemptions can apply to DSOs with less than 100,000 customers. Small DSOs exist in most MS and exemptions are usually applied.

[38] The framework guidelines and network codes are the legal vehicles for the implementation of the Target Model governing the operation of the integrated European Electricity Market. See: http://www.acer.europa.eu/Electricity/FG_and_network_codes/Pages/default.aspx.

Strategic Cost-Efficient Roll Out Of Recharging Infrastructure

In order to ensure the free movement of PEVs across the EU, recently proposed legislation from the European Commission[39] sets out minimum coverage requirements for electric recharging points for all 27 Member States, 10 percent of which should be publicly accessible, to be implemented by the end of 2020. The European Commission recommends that Member States mobilise private investment. Italy provides an interesting example of how to approach this. The Italian regulator used a competitive call, inviting participation of DSOs and other market actors, for demonstration projects to test different business models for delivery of PEV recharging infrastructure.[40]

To accelerate deployment of PEVs, regulatory intervention may be needed in the early stages to support roll out of PEV public charging infrastructure, particularly kerbside charging for households without garages. The regulator will also need to monitor developments carefully and consider whether the DSO will need to fill gaps at a later date where infrastructure provision has not been met by the market.

Conclusion

Dispatchable demand response through an aggregator offers perhaps the best opportunity to fully exploit the advantages of PEV flexibility to address the requirements of variable RES. A priority action for regulators will be to remove or minimise any existing regulatory or market barriers that prevent demand response from participating in electricity markets on a comparable basis to generation. It will take time, however, for responsive demand-side services to emerge even after the markets permit them. Time-varying pricing offers an interim solution that can help to immediately mitigate the risk of overload to distribution networks and provide PEV owners with some compensation for this service. Time-varying pricing with a real-time component (such as RTP), combined with an automated control system such as a smart charger, improves the statistical reliability of self-automated response.

Regulators can also ensure that DSOs are adequately incentivised to actively and efficiently manage the grid, integrating DER including PEVs. Use of a performance-based framework (PBR) which is revenue-based can break the link between sales growth and DSO financial performance but still incentivise cost efficiency. The framework can also link DSO performance to achievement of public policy goals.

Unidirectional charging strategies to deliver grid services through postponement or interruption of recharging, for which the EV owner can be compensated, can be promoted immediately at little additional cost to vehicle owners. Conventional ancillary services, such as frequency response and secondary reserves, can provide an early boost to PEV deployment, significantly offsetting the electricity

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[39] European Commission. (January, 2013). Proposal for a Directive on the deployment of alternative fuels infrastructure. COM (2013) 0012.

[40] Schiavo, L.L., Dalfanti, M., Fumagalli, E., and Oliveri, V. (2013). Changing the regulation for regulating the change: Innovation-driven regulatory developments for smart grids, smart metering and e-mobility in Italy. *Energy Policy* 57 (2013) 506-517. Selected projects receive a financial contribution per charging point per year over three years. Regular reporting of results is required for dissemination purposes and lack of data is financially penalised. The costs of PEV recharging infrastructure are covered by PEV users through a network tariff set by the regulator.

refuelling cost (though the value of frequency response will quickly decline as PEV numbers increase). As variable RES increases, so too will the need for flexible demand response with high ramping and cycling capabilities. Storage and the provision of time-shifting flexible services could potentially become a major contributor to value at higher levels of PEV penetration. Further, advances in PEV technologies may mean that greater value can be extracted in the longer term by PEVs through bidirectional charging.