SHAKTI SUSTAINABLE ENERGY FOUNDATION

Alliance for an Energy Efficient Economy

# VEHICLE-GRID INTEGRATION A NEW FRONTIER FOR ELECTRIC MOBILITY IN INDIA

## EXECUTIVE SUMMARY

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Executive Summary: VEHICLE-GRID INTEGRATION – A NEW FRONTIER FOR ELECTRIC MOBILITY IN INDIA

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Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

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# Importance of Managing EV Charging

Electrification of vehicles has its share of benefits as well as risks to the power distribution companies (DISCOMs). While EV adoption can potentially result in a substantial increase in revenue for DISCOMs from additional electricity sales due to EV charging, the gains may be accompanied by various risks. The risks are at multiple levels – from the DISCOM's service area to the feeder level. The EV charging demand may increase the peak load in the DISCOM's service area, which could have a significant impact on the cost of electricity supply.

EV charging is expected to have a more significant impact at the local level of the distribution network. EV charging loads at charging points are anticipated to be very dynamic, with spikes in the demand curve. This can potentially have a serious impact on the distribution network, especially in distribution areas with low available hosting capacity. Unmanaged EV charging at the charging stations can hamper smooth power system operations, by causing voltage instability, harmonic distortion, power losses, and degradation of reliability indices.

To manage or avoid these impacts on the power system, there are both passive and active solutions, as mentioned below.

- **Passive management,** influencing EV users' charging behaviour using specially designed electricity tariffs (e.g. Time-of-Use (ToU) charges, demand charges, or customer fees) or incentives to encourage charging at a certain level and/ or a certain time (e.g. rebates for lower level charging or charging during off-peak hours)
- **Unidirectional active management** of charging, such as ramping charging levels up or down (referred to as V1G)
- **Bidirectional active management** of electricity, entailing vehicle-to-grid power flow (referred to as V2G)

Vehicle-Grid Integration (VGI) refers to this entire gamut of EV charging management solutions to mitigate the negative impacts of uncontrolled EV charging on the power system.

# VGI, Not Just A Charging Management Solution

The benefits of VGI extend beyond EV charging load, as it can provide useful services to the grid. Hence, VGI is often defined as "*the many ways in which a vehicle can provide benefits or services to the grid, society, the EV driver, or charge point operator by optimising plug-in electric vehicle interaction with the electrical grid*". Figure ES 1 summarises these potential benefits, grouped by topic/beneficiary.

It should be noted that, in order to realise the abovementioned benefits, major technological interventions are required, which may have economic implications, along with a conducive regulatory ecosystem enabling the introduction of different market mechanisms to harness the full potential of VGI.

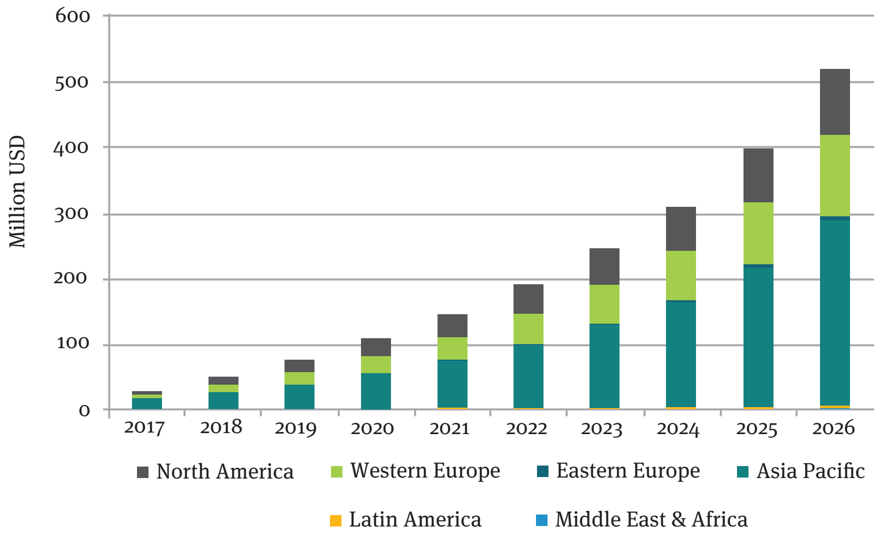
| Benefit | Description |
|---|---|
| **Customer Benefits** (EV Owners/ Charging Station Operators) | • Reduction in electricity bills through use of ToU rates and/ or avoiding high demand charges<br>• Provision of back-up power in case there is a supply disruption or issue with power quality<br>• Increased solar self-consumption to address localised overgeneration from solar energy |
| **Distribution System Benefits** | • Deferral of distribution capacity upgrades<br>• Better integration of renewables and reduction in backflow on distribution system in high solar penetration areas<br>• Voltage support and resiliency services (reliability services) |
| **Transmission System Benefits** | • Deferral of transmission capacity expansion<br>• Better integration of renewables<br>• Voltage support and primary frequency response<br>• Operational efficiency and black-start services |
| **Wholesale Market Benefits** | • Primary and secondary frequency regulation (response)<br>• Reactive power support and management of energy imbalances |
| **Compliance Benefits** | • Utilities/ consumers: achievement of regulatory requirements and/ or renewable energy targets<br>• Cities/ states: achievement of renewable energy targets |
| **Societal & Environmental Benefits** | • Reduction of power system/ transport sector's carbon footprint<br>• Reduction of criteria air pollutants and air toxics<br>• Creation of economic opportunities<br>• Generation of employment and upskilling opportunities |

**ES 1: RANGE OF VGI BENEFITS AT DIFFERENT LEVELS AND FOR DIFFERENT STAKEHOLDERS**

*Source: California Public Utilities Commission (California Public Utilities Commission, 2017)*

## Early Green Shoots of VGI Market

VGI implementation in real-world situations is at an early stage; the application of VGI technologies in grid services is just beginning. Pilot projects driven by academia, as well as industry, across the world are exploring various aspects of VGI. The EV market is currently mature in several locations worldwide, including North America, Western Europe, China, and the Organisation for Economic Co-operation and Development (OECD) Asia Pacific nations. According to Navigant Research estimate, the global market for VGI enabling technologies, such as bidirectional DC EVSE and EVSE networking software for VGI services, reached nearly United States Dollar (USD) 28.4 million in 2017. By 2026, the market is forecast to grow steadily at a compound annual growth rate (CAGR) of 35.8% to reach USD 447.5 million. In total, it is estimated that the market for VGI enabling technologies and actual VGI services will reach nearly USD 517.5 million by 2026, as shown in Figure ES 2. It should be noted that this forecast was based on the market health and sentiment before the world economy experienced an unprecedented shock due to the Coronavirus disease 2019 (COVID-19) pandemic. The current economic crisis will inevitably have an impact on the adoption of advanced VGI applications in the near future.




**ES 2: VGI TECHNOLOGY AND SERVICE REVENUE BY REGION: 2017–2026**

*Source: Navigant Research*

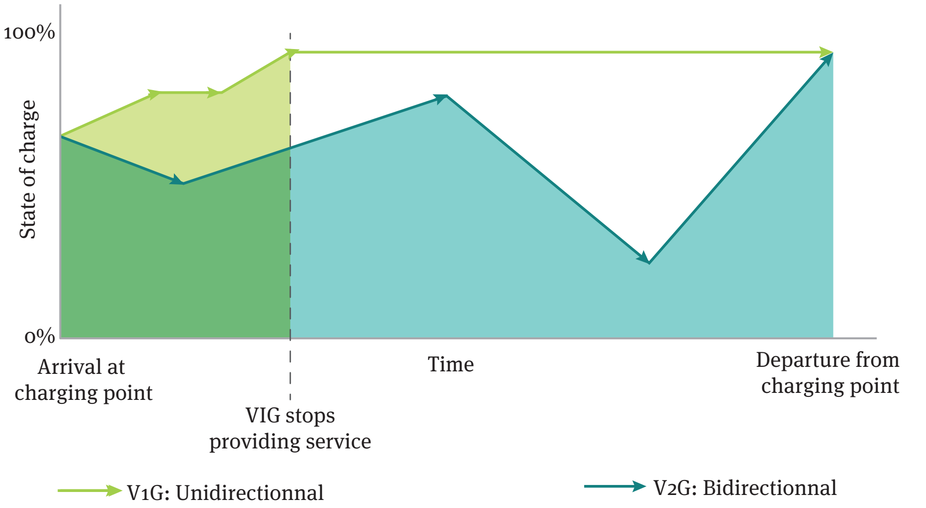
Globally, pioneering VGI projects have provided interesting insights into different aspects of VGI technology.

# Value Streams of VGI

A plethora of new opportunities open up for the power market with the help of V1G and V2G. According to experts, there are four key benefits one should consider in the techno-economic analysis of V1G and V2G:

1. **Peak shaving:** V1G and V2G are well suited for peak shaving. The EV batteries can charge during off-peak hours, thus filling the valleys in the load curve through V1G. If there is bidirectional capability with V2G, then EV batteries can be discharged when there are peaks in demand and excess power is required. Thus, V1G and V2G can potentially help utilities manage their daily load and meet the peak demand efficiently and cost-effectively.
2. **Arbitrage opportunities:** V2G makes it possible for the EV market players to trade on the power markets. When electricity prices are low, energy can be bought and stored by charging the vehicles. When the prices become high, the stored energy can be sold on the power market.
3. **Frequency regulation:** The power grid is set up at a frequency of 50 hertz (Hz). When there is a supply - demand mismatch, there will be variations in frequency, and this has an impact on the grid stability. Since EV batteries can respond to the changes within a few seconds, this is a much more efficient solution compared to slow responding mechanical, spinning reserves. V2G enabled EVs can therefore be competitive in the ancillary service market for frequency regulation.
4. **As a RE storage unit:** EVs can be charged either when there is a high volume of renewable energy in the grid but not sufficient demand or directly by RE sources (e.g. solar photovoltaic (PV)), and the EVs can then store the energy. When there is an increase in power demand in the grid, the charged EVs can feed the stored renewable energy back into the grid, thus maximising RE utilisation and minimising the power system's carbon footprint.

Are V1G and V2G at par in terms of grid services value? Due to bidirectional energy flow, V2G has an edge over V1G in providing grid services, as shown in Figure ES 3.

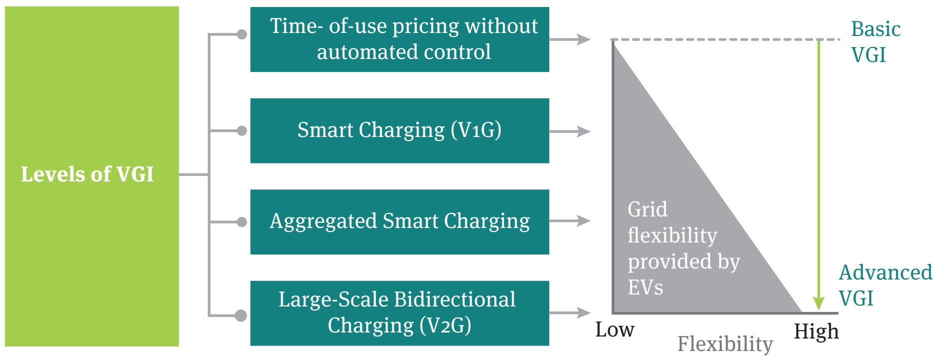



**ES 3: PROPORTION OF GRID SERVICES THROUGH V1G AND V2G**

*Source: IEA and AEEE analysis*

The lines in the graph indicate how V1G and V2G can impact the EV state of charge. In V1G's case, charging can be done at different times, but eventually reaches 100%, after which no further changes can happen; in contrast, V2G enables the EV battery to be discharged and charged according to the needs of the grid, thus offering more flexibility. According to the International Energy Agency (IEA), V2G can potentially unlock 9 times more value from EV-grid integration than V1G.

It should be noted that the actual economic value of VGI depends not just on the adopted use case, but also on the scale of implementation. For better economic return from V1G or V2G, achieving the required scale is essential. Hence, VGI is considered to have three levels -- Smart Charging (V1G), Aggregated Smart Charging, and Large-Scale Bidirectional Charging (V2G). Figure ES 4 summarises how the value of flexibility services to the grid varies among the different VGI applications.




**ES 4: VGI APPLICATION VALUE IN GRID FLEXIBILITY SERVICES**

*Source: AEEE analysis*

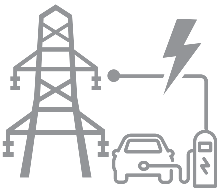
Although the value of V2G-based grid services is potentially greater than that of V1G, realising those benefits may not be a straightforward task. There are a set of major technological requirements that could potentially impact the on-ground implementation and the possibility of scale-up in the near future.

## Technology Dependence – Is It A Barrier?

Technology is an intrinsic part of VGI implementation. Almost all the major components of electric mobility would require "upgradation" to enable VGI, right from the charging technology to the EV and its battery. Hence, VGI implementation would add considerable cost to the charging infrastructure and to the EV.

**Charging technology**, which closely binds mobility to the electricity sector, requires sophisticated features to enable EV participation in grid services. The basic difference between a simple EVSE and an EVSE used in V1G is that the latter shares a data connection with an EV, as well as with the charging point operator. As opposed to a simple charging device that is not connected to the cloud, smart charging allows the charging service provider to monitor, manage, and restrict the use of chargers remotely to optimise energy consumption. Moreover, smart chargers can be enabled to respond to price signals on their own. A major operational advantage of smart chargers is that their functions can be modified at any point in time; it is easy to add and remove features and design a system to meet one's needs. Hence, the costs of smart chargers vary depending on the features.

V2G goes one step further and enables the feeding back of energy stored in the EV battery into the grid, apart from the usual energy flow during EV charging to the EV battery. V2G requires additional electrical equipment compared to standard or smart charging, such as a bidirectional inverter to convert the DC output power from the on-board EV battery to AC. Control units are also required for efficient, reliable, and safe battery charging and discharging, along with upstream communication protocols to manage these interactions between EVs and the grid. A number of additional technical requirements need to be met to enable V2G implementation. Globally, there are few V2G-ready EVSEs. Moreover, because of the need for expensive hardware, V2G EVSEs are much more costly than smart chargers.



**THE EV, ALONG WITH ITS BATTERY, IS AT THE CORE OF VGI.**

The **EV**, along with its battery, is at the core of VGI. As in the case of charging technology, the vehicle features required for V2G application differ considerably from those needed for V1G. As data sharing between an EV and EVSE provides the basis for smart charging, the vehicle design should allow for that. Fortunately, most EV models with advanced batteries and a Battery Management System (BMS) currently available on the market, including in India, have the necessary capability. Hence, smart charging does not require a different set of specially equipped EVs. However, this does not hold true for V2G; in this case, the EV should have the discharge functionality. Currently, only a few commercially available EV models have the potential to participate in V2G. None of these EV models are currently commercially available in India.

**Battery health** is also an important consideration in implementing VGI. Battery performance deteriorates gradually with the number of charging-discharging cycles. For this reason, an OEM's battery performance warranty is highly valued and one of the key considerations at the time of vehicle purchase. Usually, such warranties are given based on the years of vehicle usage or distance travelled and are often bound by certain clauses on vehicle usage. More often than not, OEMs de-recognise their warranties for EVs if they are used for purposes other than mobility. The extent to which this affects VGI implementation should therefore be examined.

As the battery has to undergo additional charging-discharging cycles to participate in V2G, the typical OEM clause on the withdrawal of EV battery warranty on the grounds of non-mobility use of the battery remains a major barrier to its implementation. There have been several studies on the subject of effect of additional use of the EV battery on battery health, but with no unanimous conclusions regarding this issue. Under such circumstances, EV owners are less likely to participate in a V2G programme.

## Techno-Economic Comparison of V1G and V2G

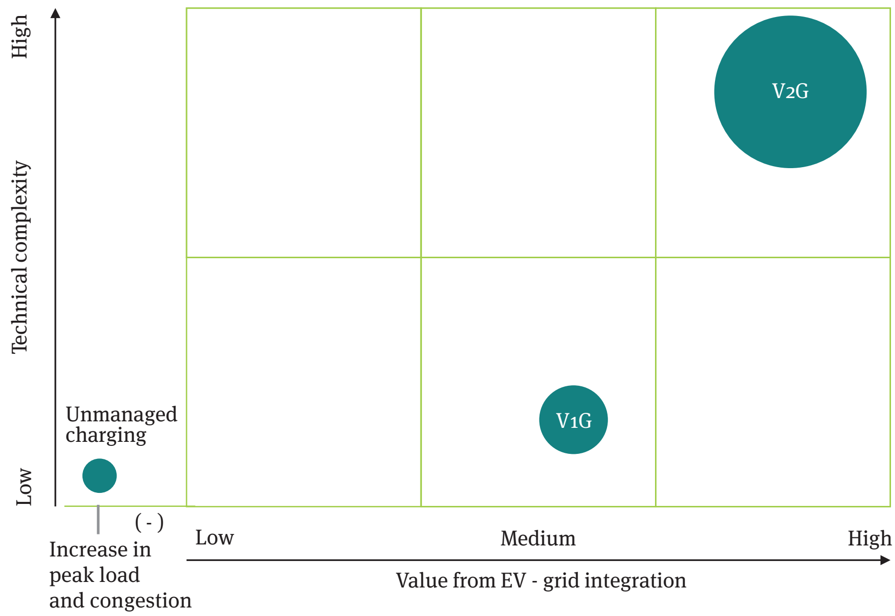
It becomes clear that V2G can potentially offer substantial value but is complex and expensive too, whereas V1G has limited complexity and offers value less than V2G (Figure ES 5).

| Values from VGI | Technical complexities | | | |
|---|---|---|---|---|
| | Smart charger | Battery health | Smart charger with bidirectional functionality | Suitability of EV |
| Peak shaving | √ | √√ | √√ | √√ |
| Congestion management | √ | √√ | √√ | √√ |
| Frequency regulation | √ | √√ | √√ | √√ |
| Increase in RE uptake | √ | √√ | √√ | √√ |
| RE storage | | √√ | √√ | √√ |
| Arbitrage opportunities | | √√ | √√ | √√ |

V1G √ V2G √√

**ES 5: SNAPSHOT OF BENEFITS AND COMPLEXITIES OF V1G AND V2G**

From the three-dimensional matrix on the techno-economic comparison of V1G and V2G vis-à-vis unmanaged charging (Figure ES 6), one can infer that although V2G enables a greater range and value of grid flexibility services compared to V1G, it also involves a highly complex set of technological factors, which, in turn, increases its cost of implementation. In contrast to VGI, unmanaged charging does not require a sophisticated charger, but it potentially has a considerable negative impact on the power system.




**ES 6: TECHNO-ECONOMIC COMPARISON OF UNMANAGED CHARGING, V1G, & V2G**

*Source: AEEE analysis*

## Stakeholder Views

EV adoption and integration with the power grid through VGI depend on the decisions and actions taken by different stakeholders. VGI is a multilateral concept involving a variety of different stakeholders. The various stakeholders have different benefits to pursue, different barriers to overcome, and different perspectives on the uptake of EVs and their integration with the grid. During consultation with battery experts, DISCOMs, Research and Development (R&D) institutions, fleet operators, and charging service providers, views of the stakeholders on some key issues related to VGI have emerged, as captured in Table ES 7.

**ES 7: STAKEHOLDER VIEWS ON KEY ASPECTS OF VGI**

| Key issue | Battery experts | R&D institutions | Charging service providers | Fleet operators | DISCOMs |
|---|---|---|---|---|---|
| Readiness for V1G | ✓ | ✓ ✓ | ✓ ✓ | × | ✓ |
| Readiness for V2G | | × | × | × | × |
| Technical feasibility of VGI | ✓ | ✓ ✓ | ✓ | × | ✓ |
| Economic feasibility of VGI | | | | × | |
| Suitability of e-2Ws & e-3Ws for VGI | | × | × | × | × |
| Suitability of e-4Ws & e-buses for VGI | | ✓ ✓ | ✓ ✓ | ✓ ✓ | ✓ ✓ |
| Necessity of battery degradation research | ✓ ✓ | ✓ ✓ | | | ✓ ✓ |
| Profitability of VGI for fleet operators | | ✓ | ✓ | × | ✓ |
| Feasibility of VPP in India | ✓ | ✓ | | | |

✓ ✓ Completely Agree
✓ Partially Agree
× Do Not Agree

Moreover, some important recommendations regarding VGI implementation came out of the stakeholder consultation which are as follows:

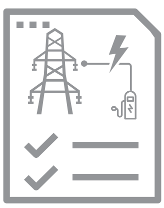
- VGI pilot projects need to be carried out.
- It is important to conduct research on EV battery degradation in V2G.
- Regulators need to be educated on different aspects of VGI.
- Slow starters should be mandatory in V2G chargers.
- Electric four-wheelers and e-buses are potential candidates for testing V2G feasibility.
- It is important to frame regulations to facilitate commercialisation of VGI.
- It is critical to analyse the profitability of participation in VGI for EV fleet operators in Indian cities.

## Importance of Electricity Price Signals

A prerequisite for VGI implementation is appropriate price signals for electricity. Price signals to EV users are needed to shift EV charging to off-peak hours and coincide it with the availability of RE sources, thus enabling V1G and maximising its potential benefits. Furthermore, price signals can encourage EV users to participate in V2G programmes. The first and most simple step in providing appropriate price signals is implementing ToU electricity rates. In India, some form of ToU tariff is implemented by many states, with varying rates between peak and off-peak hours. This is referred to as a Time-of-Day (ToD) tariff.

While ToU tariffs are useful in EV load management, they may become less effective as EV penetration in a given region increases. A key concern regarding ToU rates is that they may lead to creation of new peaks when the EVs start charging. Introducing real-time electricity pricing as an extension of ToU rates is considered an important regulatory mechanism for the future. A key concern with respect to real-time pricing is the complexity in its implementation. Customers may find it too complex to realise the benefits.

## Defining EV as A Resource and Allowing Aggregation



**THE FUNDAMENTAL REGULATORY STEP TO ENABLING VGI IS RECOGNISING EV AS A GRID "RESOURCE".**

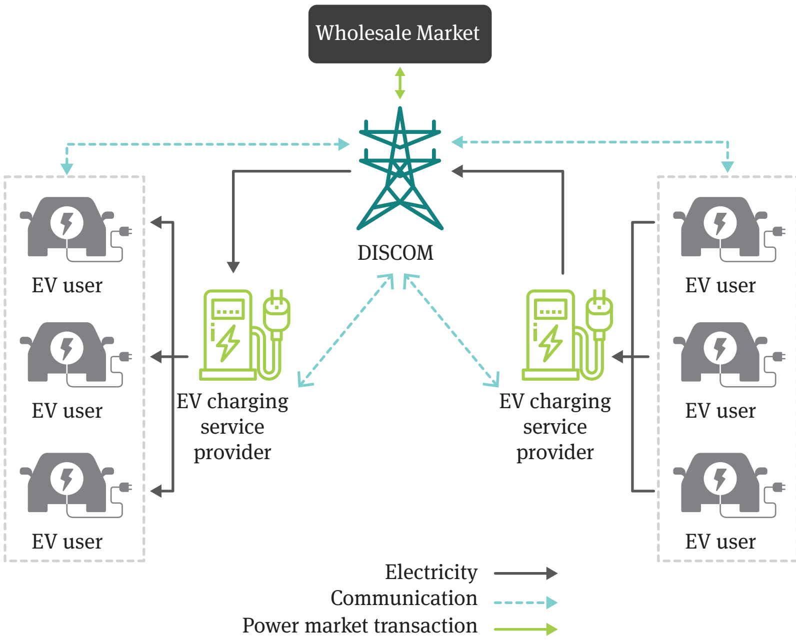
The fundamental regulatory step to enabling VGI is recognising EV as a grid "resource". Appropriate provisions are necessary in regulations to clearly define how EVs should be treated as a "resource", since EV charging involves multiple elements: the vehicle with the battery, charging station, host facility (in case the charging station is part of a facility with a different purpose), and aggregator. The implications of the definition of "resource" would be varied and at different levels.

A small number of EVs[1] at a given location is not sufficient to act as a grid resource. EV aggregation is essential in order to adequately respond to wholesale market signals. it would be important to find out the minimum number and mix of EVs required to participate in the wholesale market. Since aggregation of EVs spread out over an area is the most plausible option, one has to check whether the applicable regulations permit aggregation of geographically-dispersed resources and, if so, what the permitted geographic spread is.

1 Only heavy duty EVs in small numbers can viably participate as a resource, due to their large battery sizes.

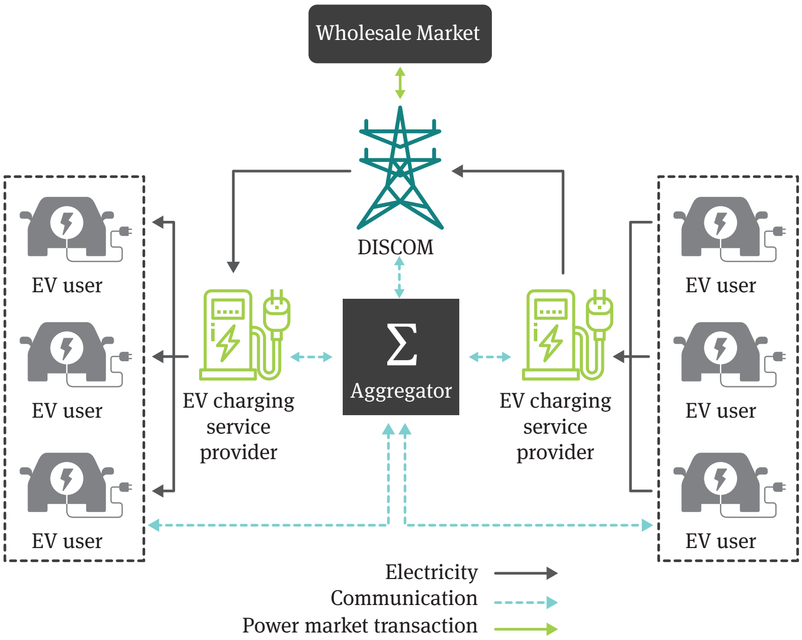
## DISCOM – A Convenient Choice for The Aggregator Role

The DISCOMs are an important actor in this resource aggregation. There are four potential aggregators models with different levels of DISCOM involvement: (i) DISCOM as the sole aggregator; (ii) DISCOM as meta-aggregator; (iii) competitive aggregation market without DISCOM participation; and (iv) a hybrid approach where both DISCOMs and non-regulated firms can serve as aggregators.  In the first model, the DISCOM would be the sole entity responsible for EV aggregation (Figure ES 8). However, for effective management, the DISCOM has to have detailed knowledge about EVs, customers' travel behaviours and preferences, etc., which is beyond its traditional scope. Moreover, this approach will create a market monopoly.



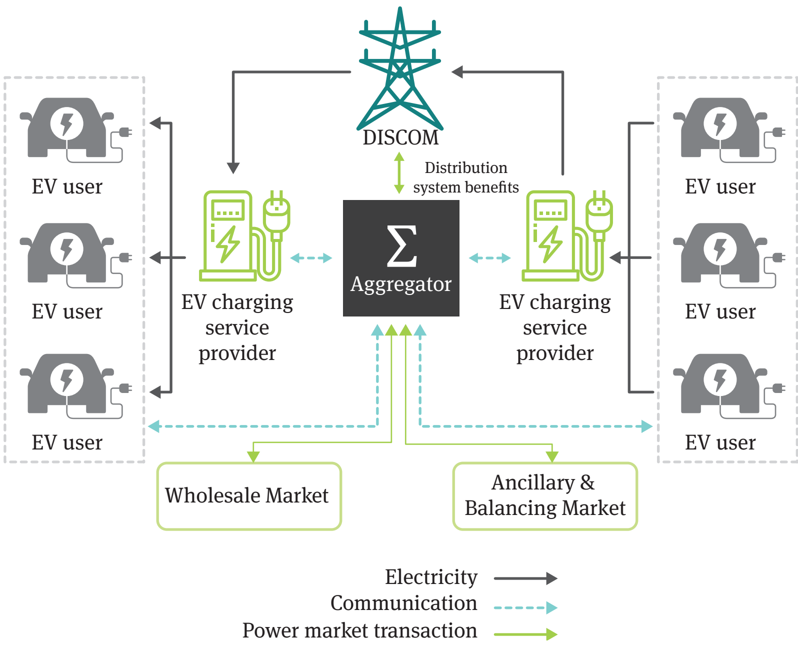

**ES 8: DISCOM AS THE SOLE AGGREGATOR**

When the DISCOM acts as the meta-aggregator, a non-DISCOM third party aggregator serves as the intermediary between the customer and the DISCOM (Figure ES 9). In this case, the DISCOM has no direct interaction with the customer, and the aggregator(s) has no direct involvement in the wholesale market. A key limitation in this model is that by only allowing DISCOMs to represent the EV load on the wholesale market, this may reduce competition in the wholesale market. In addition, the aggregator(s) would be at the mercy of the DISCOM in terms of compensation.



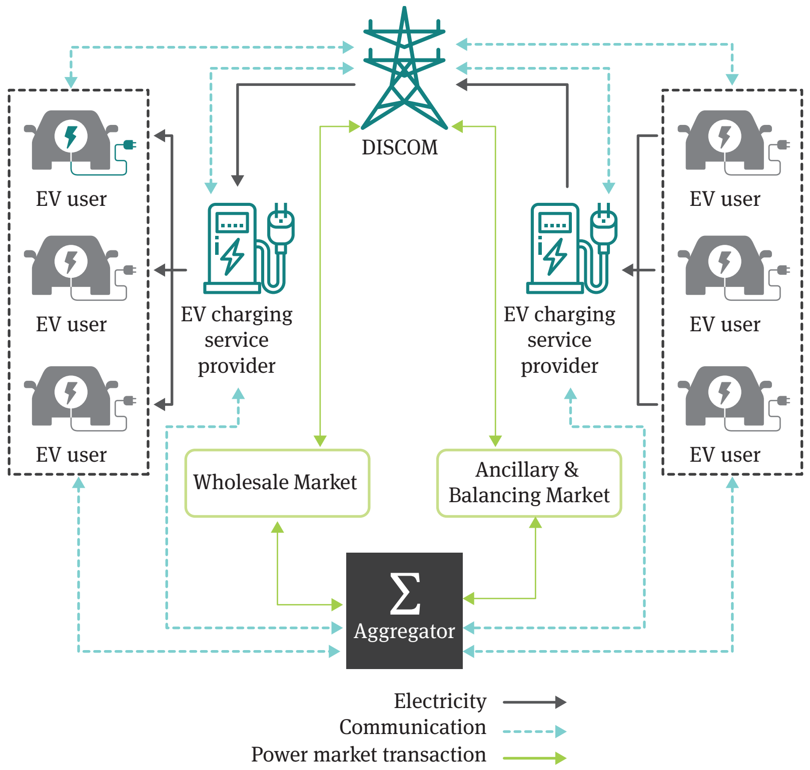

**ES 9: DISCOM AS META-AGGREGATOR**

In the case of a competitive aggregation market without DISCOM participation, non-DISCOM aggregators are solely responsible for aggregating EVs to provide services to both the wholesale and ancillary service markets and to the DISCOM for distribution system benefits (Figure ES 10). In order for aggregators to provide services to the DISCOM, the DISCOM needs to develop price signals that reflect the costs and benefits of EV charging and grid services. Furthermore, realising DISCOM benefits and allowing third-party wholesale access to the EV resource would require regulations that allow these two functions to co-exist.




**ES 10: COMPETITIVE AGGREGATION MARKET WITHOUT DISCOM PARTICIPATION**

The fourth model, i.e. a hybrid market approach, allows DISCOMs and third-party aggregators to compete for customers, rather than limiting the involvement of DISCOMs and other actors (Figure ES 11). In such a scenario, a regulatory framework would be necessary to enable all these entities to compete on a level playing field and maximise opportunities to reap both wholesale and distribution benefits.




**ES 11: HYBRID APPROACH**

## Critical to Set Interconnection Requirements and Communication Standard

Interconnection requirements are especially important for the application of EVs in grid storage. Based on the implementation model, the regulator and utility have to determine what interconnection requirements would be necessary for EV storage resources. Due to bidirectional energy flow in the case of V2G, the interconnection requirements are different from those of resources with unidirectional energy flow. Net metering rules may be used to simplify these requirements.

VGI involves two types of communication functions: receiving wholesale market signals for the resource and sending meter performance data to the wholesale market. A communication standard is essential to sending messages between the aggregator (either the DISCOM or non-DISCOM third party) and the wholesale market. Standards will also likely be required for downstream communication to ensure that each element of the VGI programme is equipped to respond to the message. Such downstream communication can use existing smart grid communication standards, such as OpenADR or SEP 2.0, or new standards, including ISO 15118.

## Effective to Leverage Existing Regulations

It is important to identify the existing policy, legislative, and regulatory provisions that can be effectively leveraged to create the building blocks for VGI implementation. As far as tariffs for EV charging are concerned, the electricity regulators of 18 states and 5 UTs have stipulated specific rates in their respective tariff orders through November 11, 2019. However, treatment of EVs as a consumer category and the corresponding rate design vary across states. Some states have introduced a separate category called Public EV Charging Stations (such as UTs, Goa, etc.), which is distinct from existing consumer categories, whereas other states (e.g. Andhra Pradesh, Chhattisgarh, and Punjab) have specified EV tariffs under the existing categories, such as non-domestic or non-commercial. Such EV categorisation could have an impact on the conceptualisation of VGI programmes; in the absence of EV-specific tariffs, designing a VGI programme would be challenging. What about ToU tariffs for EV charging? The study has found that there are only three states (Uttar Pradesh, Kerala, and Maharashtra) that have introduced ToD rates specifically for EV charging. In few states, ToD rates are applicable by default for EV consumers based on certain requirements. The existing ToU/ ToD rates can be leveraged to implement VGI programmes in these states. However, as highlighted above, static ToU rates have inherent limitations in achieving load flattening. Hence, the introduction of real-time tariffs is required. In India, there is currently no precedence for application of real-time electricity tariffs.

The current Indian regulatory framework supporting Demand Side Management (DSM) interventions merits examination as it can be used to facilitate VGI implementation. The fact that DSM Regulations exist in many states in India is a positive thing. The provisions in these regulations can be used to design and implement VGI in the country. Some state regulations have advocated demand response initiatives, which provide the foundation for executing V1G, in particular. However, the regulations have neither introduced the concept of “resource aggregation” nor defined the role of an “aggregator”. This is a major gap that could make it difficult to scale up VGI implementation and also limit adoption of innovative business models.

**BECAUSE OF THE BIDIRECTIONALITY IN ENERGY FLOW IN V2G, THE INDIAN REGULATORY FRAMEWORK DEALING WITH PROSUMERS CAN BE USED.**

Because of the bidirectionality in energy flow in V2G, the Indian regulatory framework dealing with prosumers[2] can be used. The current Net Metering Regulations (or Gross Metering Regulations) can set the basic framework for V2G implementation in the country. However, these regulations are designed for implementing grid-connected rooftop solar PV systems, and, hence, necessary amendments have to be incorporated to expand the scope to recognise the concept of Virtual Power Plant (VPP). Regulations on applicable rates for electricity export, settlement period, limit on system capacity, communication capability, etc. would affect the design of VPP projects and thus be important for VPP developers.

While regulations on prosumers pave the path to implement VPPs, the ability of the grid to interact with consumers, including prosumers, is crucial to realising the benefits of V1G and V2G. In this context, smart grids are considered an important infrastructural requirement for VGI implementation. Forum of Regulators (FoR) developed the Model Smart Grid Regulations in 2015 for adoption at the state level. The Model Regulations recognise

2 According to Central Electricity Authority regulations, “prosumer” means an agent, including energy storage systems, that consumes electricity from the grid and can also inject electricity into the grid, using the same point of connection.

V1G and V2G as important elements of a smart grid project and also cover the supporting elements of VGI, such as Advanced Metering Infrastructure, Demand Response, dynamic tariffs, ToU tariffs, critical peak pricing, real-time pricing, etc. From the regulatory point of view, the Smart Grid Regulations can effectively enable VGI implementation in India.

## Major Gaps in The Regulations and The Power Market

**A KEY GAP IS THE EXISTING INDIAN REGULATIONS LACK PROVISIONS THAT PERMIT "AGGREGATION" OF DISTRIBUTED ENERGY RESOURCES IN GENERAL, INCLUDING EVS, TO PROVIDE GRID SERVICES.**

While there are several regulatory provisions in India that are supportive of VGI or its different elements, directly or indirectly, and, if needed, they can be amended to effectively address gaps or ambiguity, there are certain major gaps in the existing regulatory framework that warrant attention and necessary action. A key gap is the existing Indian regulations lack provisions that permit "aggregation" of distributed energy resources in general, including EVs, to provide grid services. Consequently, the different principles or implementation models for resource aggregation are currently not covered in the regulations, which is a major barrier to VGI implementation in India.

Another significant challenge to implementing VGI in India is the lack of an ancillary service market in the country. Pilot projects have already shown that with aggregation and fast demand response, EVs can be an effective resource for frequency response services. Unfortunately, India's electricity sector does not yet have a market for ancillary services such as Fast Tertiary Control, Secondary Frequency Control, Voltage Control, and Black-Start. Only slow tertiary reserves (with response times between 15 to 60 minutes) are currently used. In the absence of an ancillary service market, the full benefits of VGI cannot be tapped.

## Way Forward for India

V1G can be achieved in India without waiting for new charging technology to emerge. The hallmark of V1G or smart charging is that its implementation is neither contingent on complex and expensive new EV or charging technologies nor requires significant regulatory and market reforms. Appropriate price signals are the most important tool needed to implement V1G. Furthermore, unlike V2G-enabled bidirectional chargers, smart chargers have been commercialised in advanced markets and are becoming a mainstream solution. Such smart chargers are also available on the Indian market, albeit to a lesser extent, and many of the existing installed chargers already have smart features, of varying degree.

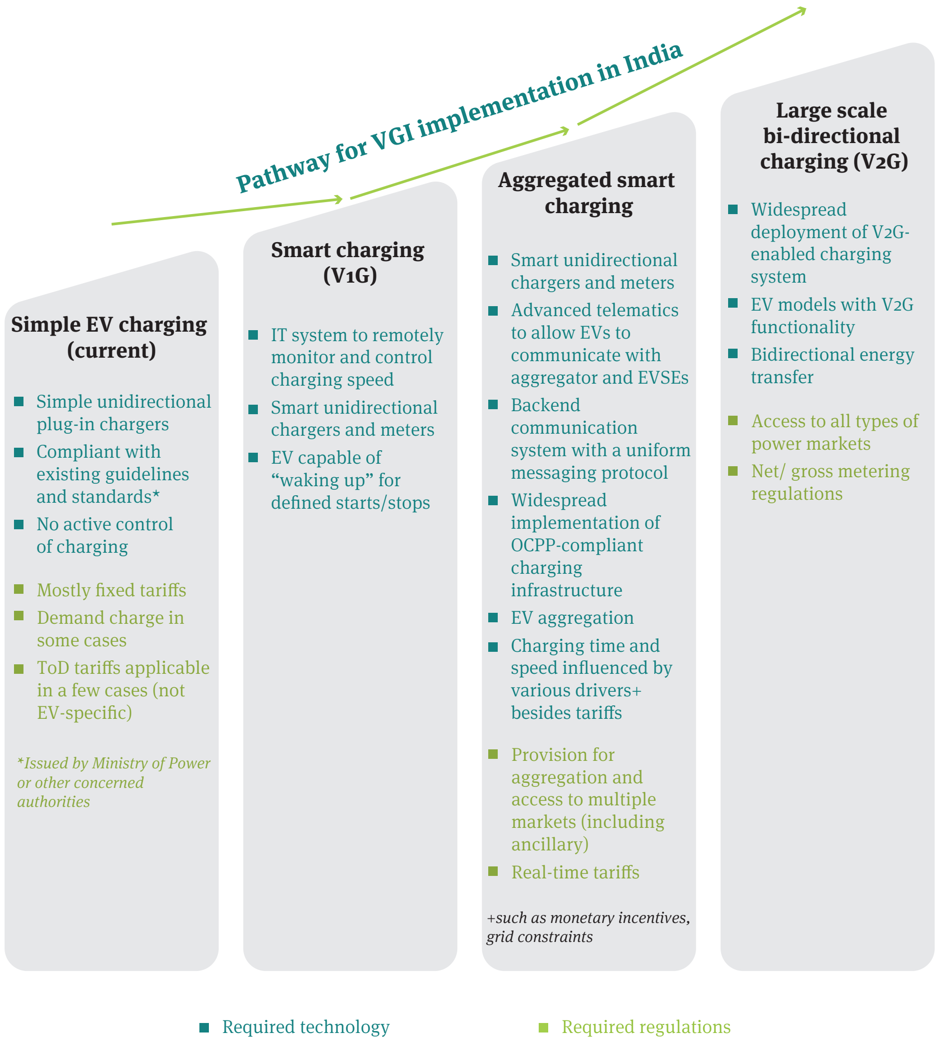
**APPROPRIATE PRICE SIGNALS ARE THE MOST IMPORTANT TOOL NEEDED TO IMPLEMENT V1G.**

However, lack of the necessary backend communication system – with a uniform messaging protocol that enables communication between charging point operators and Central Management System – is a key barrier to V1G implementation in India. The Central and State Nodal Agencies, two important oversight authorities in the country, should mandate all smart charging service providers to install OCPP[3]-compliant charging equipment and create a central cloud-based backend system (Charging Station Management System) adhering to the OCPP communication protocol, to enable real-time charging data transfer to a Central Management System, remote modification of charger configuration, and remote charging session control. This will

3 Open Charge Point Protocol

also allow the smart charging network to accommodate different charging technologies, EVs, and charging point operators.

Considering the level of maturity of India's e-mobility and power markets and the status of VGI internationally, a phase-wise VGI implementation roadmap could be effective for the country, as depicted in Figure ES 12. VGI has different use cases, and each of them has a unique set of challenges and value propositions. And the greater the potential value, the more complex the solution is to implement. The three major levels of VGI – V1G, Aggregated Smart Charging, and V2G – can be considered sequentially for VGI implementation, i.e. achievement of one can be regarded as the stepping stone to the next level.




**ES 12: PROPOSED VGI IMPLEMENTATION PATHWAY FOR INDIA**

The large-scale uptake of VGI would depend on the particular solution's value proposition and ease of adoption by end-users and other actors. It is likely that a number of winning use cases will begin to emerge, based on a pilot offering to different EV user groups and sets of standard commercial arrangements between new and existing actors in the power and mobility sectors. Efforts should be made to encourage international collaboration and knowledge exchange on VGI. A large amount of knowledge is accumulating from research and demonstration projects around the world, and it is crucial that this is consolidated in order to move forward with the commercialisation of VGI solutions, taking into account the local context.