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ADVANCED PLASTIC RECYCLING FOR CIRCULARITY

VEHICLE-TO-GRID TECHNOLOGIES FOR GRID SUPPORT

ADVANCED PLASTIC RECYCLING FOR CIRCULARITY

INTRODUCTION

Driven by increasing consumer awareness, governments and corporations are setting aggressive targets to promote plastic recycling. Incumbent mechanical recycling infrastructure is ill-equipped to handle post-consumer waste and often leads to low and inconsistent recycling rates or poor-quality recyclates. In some cases, waste-to-energy represents a feasible alternative to landfilling, although incineration facilities must use scrubbers and filters to bring emissions within acceptable levels. Emerging advanced plastic recycling (APR) technologies such as imaging systems, AI-driven sorting and novel cleaning processes can improve recycling efficiency significantly, often as turn-key additions to existing facilities. Chemical recycling techniques like pyrolysis, gasification, and solvent-based processes can depolymerise mixed waste into oils and polymer precursors, moving industries such as textiles and packaging closer to true circularity.

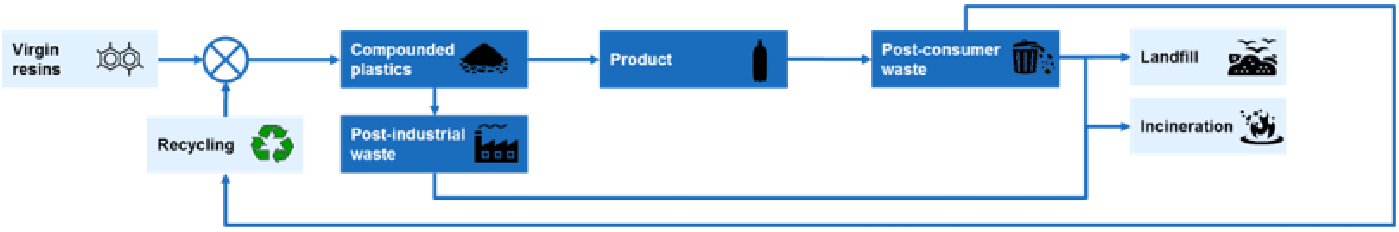

Figure 1. Simplified incumbent plastics lifecycle.
Source: Lux Research

Unique selling proposition

The key focus of most APR technologies is solving challenges related to feedstock heterogeneity from post-consumer plastic waste. Incumbent mechanical recycling technologies rely on upstream, often manual sorting, and only reliably process clear, pre-cleaned single-polymer plastics such as polyethylene terephthalate (PET). Additionally, contaminants that enter the process reduce the quality of recyclates; end users thus need to add virgin plastics to the mix to ensure compliance with quality standards. To maximise the effect of emerging APR technologies, an appropriate collection strategy must be implemented in parallel.

In principle, chemical recycling reduces plastics to their chemical constituents through a variety of techniques. These can be repolymerised and compounded to form virgin-grade materials again and again. The technique bypasses thorough sorting and decontamination requirements, as some impurities are filtered out during the degradation process. Adopting this process will allow hard-to-recycle plastics such as films, pigmented plastics, bottle caps, laminated plastics, and polystyrene to re-enter the supply chain.

Technology

Packaging comprises nearly 50% of the global plastic market and is subject to high regulatory and consumer focus. As such, most technological innovation occurs within the space. APR covers any technology or process beyond incumbent practices that improve efficiency, quality, and recycling rates in three steps of plastic recycling: sorting and separating, cleaning, and processing.

Sorting technologies identify and categorise contaminated mixed waste streams, and although well established, their speed and accuracy are regularly improving. These systems are usually offered as turn-key solutions for existing facilities to automate labour-intensive processes. Separation processes use more complex techniques that exploit plastics properties to sort hard-to-identify materials, fragmented waste streams, or multi-polymer packaging. Existing cleaning processes are unlikely to be challenged as they remove most contaminants at a reasonable cost, although some APR innovations can allow recyclers to minimise or bypass the need for thorough cleaning.

Stage	Technology	Description	Key advantages & limitations
Sorting	Spectroscopy and optical imaging	Spectrometers irradiate waste with near infra-red light, analysing the reflected spectrum, while high-speed cameras generate a spectral signature to identify materials.	Sorts ~125,000 items per hour with ~90 percent accuracy, including plastics with carbon black content or in chopped flake form. Optics raise efficiency by ~5 percent, but adoption is slowed by high costs of computers, detectors and data storage.
	Robotics and machine learning	Robotic sorters automate costly labour and machine-vision systems sort plastics by making assumptions based on shape and colour.	Turn-key robotic sorters can complement any form of imaging system. Machine-vision sorts only ~7,000 items per hour, although with near-perfect accuracy.
	Identification additives	Luminescent tracers added to plastic batches aid identification with spectrometric analysis.	Near-perfect sorting accuracy, but adds complexity to processing and modifies material functionality.

Figure 2a. Mechanical APR technologies

Stage	Technology	Description	Key advantages & limitations
Separation	Electrostatic separation	Polymer flakes ionised in a charging unit, allowing separation in an electric field.	Sorts contaminated mixes of similar density and removes metal particles. Some plastics require costly irradiative pre-treatment.
	Froth flotation	Separates materials, including shredded plastics, in a water medium based on density.	Additives hinder efficacy, similar densities cannot be reliably separated, and hydrophobic plastics must be wetted.
	Solvent dissolution	Waste exposed to strong solvents to remove pigments and dissolve polymers or adhesives; allows separation of multi-layered packaging.	May decompose additives and leave impurities in polymer matrix, large solvent volumes required, and strict sorting is necessary to ensure solvents target desired polymers.

Figure 2b. Mechanical APR technologies

Figure 3. Recycled plastic pellets, colour indicates a degree of contamination.
Source: Green Path Recovery

Figure 4. Clear, virgin-grade plastic pellets.
Source: Simas Plastic.

Chemical recycling technologies

Chemical recycling processes depolymerise plastics to their monomer form in a granulate or powder state, for later repolymerisation and compounding. This can overhaul the recycling system by minimising the role of sorting and cleaning and enabling high-quality outputs. Processes are either thermal, as in pyrolysis, or solvent-based, as in methanolysis, glycolysis, and hydrolysis. Each technique and depolymerisation agent corresponds to a variety of use cases depending on waste feedstock.

Pyrolysis is the most mature and promising option for a flexible chemical recycling technology. Pyrolysis involves heating plastics between 300°C to 900°C in an inert atmosphere to decompose polymers. The resulting pyrolysis oil can be converted into plastics with properties nearly- or identical to those derived from petrochemicals. In catalytic pyrolysis, a catalyst may be added to reduce the time and temperature of the process depending on feedstock conditions and desired outcome.

Pyrolysis oil can also be used as a platform to synthesise waste-based fuels, as the oil represents a potential substitute for petroleum in certain applications. However, the high cost of processing relies on fees charged to accept large quantities of waste and must therefore compete with landfill costs to remain viable.

This differs from waste-to-energy that is more concerned with landfill diversion and valorisation of non-recyclable materials that chemical processes are unable to handle. Despite the negative perception of plastics incineration, energy produced can offset emissions that would be created through other carbon-intensive methods. Additionally, landfills can sequester large volumes of methane into the atmosphere – which is 28 times more potent than CO_2 as a greenhouse gas – while flue gas scrubbers and filters capture significant percentages of the CO_2 produced by waste-to-energy facilities before it enters the atmosphere.

Technology	Description	Key advantages & limitations
Pyrolysis	Waste heated to 300°C-900°C in atmospheric pressures to weaken polymer bonds.	A simple process that tolerates diverse feedstock.
Methanolysis	Waste submerged in heated methanol solvent to selectively dissolute polymers.	High pressure (20-50 bar) required.
Glycolysis	Plastics exposed to ethylene glycol at temperatures of 180°C-240°C.	Low processing times (1-5 hours) but increases purification and separation steps. Particularly useful for PET.
Hydrolysis	Waste exposed to aqueous solution (neutral, alkaline, or acidic) to dissolve target polymers.	High pressure and time; particularly long times and acid costs for acidic hydrolysis.
Gasification	Plastic exposed to superheated steam and air to produce 'syngas'; used as natural gas alternative or raw material in chemical production.	Limited formation of air pollutants and most by-products are non-hazardous; process accepts low-quality feedstock.
Enzymatic/bio-degradation	Plastics are placed in a specialised compost heap or bio-reactor and genetically modified microbes or enzymes degrade target polymers.	Occurs in atmosphere conditions; unproven scalability; long and variable process time.

Figure 5. Chemical recycling technologies

Innovations to Watch

- **Single-polymer multi-layers:** Packaging comprised of various polymers adds significant complexity to the recycling process. Single polymer multi-layers use varying molecular weights to replicate the properties of heterogenous multi-layer packaging. Designing for recyclability can boost recycling rates with minimal capital expense. However, this represents a burden to brand owners, the least responsive players in the value chain, as more material is needed to achieve the same function for packaging.

- **Novel re-use prospects:** Finding new areas to deploy recycled, and especially low-quality, plastics can pave the way for higher re-use rates. Plastic roads are one of many possible solutions being explored by companies such as **KWS Infra**, with recyclates replacing ~20 percent of the bitumen in asphalt. Asphalt already enjoys high recycling rates, and changes to the formula could complicate the recycling process. End-of-life issues may nullify the sustainability driver of many solutions such as this, although the number of possibilities is vast.

- **Novel adhesion systems:** Pressure-sensitive adhesives (PSA) pose an issue for pulp recycling as they build up on equipment over time. New recycling compatible adhesives (RCAs) remain after pulping and can be removed by dry washing or froth flotation with efficiencies as high as 99 percent. RCAs for paper-based labels are already well established, though not for PP films. Companies such as **Avery Dennison** are exploring their use in PET products to integrate recycled content as a liner between virgin and recycled material.

ADVANCED PLASTIC RECYCLING FOR CIRCULARITY

Commercial Aspects

Mechanical recycling costs are highly dependent on the degree of waste separation achieved at the collection source. A recent study by Zonguldak Bülent Ecevit University in Turkey identified that full waste segregation at the source would enable recycling at US$0.25 per kg – cheaper than the real figure of US$0.40 per kg. Real costs also vary significantly depending on local regulatory, practical and economic conditions. A general figure for current costs for mechanically recycling PP and PET is around US$400 per tonne – averaged across all common plastics, this figure rises to US$510 – while capital expenses for a 100,000 tpa facility are around US$36 million. However, process deficiencies, lower mechanical and aesthetic performance of recyclates, and regulatory and demand changes are disincentivising factors of applying mechanical recycling to re-purpose plastics.

Chemical recycling at scale is not currently a widespread method of recycling and most commercial-scale facilities use pyrolysis to convert feedstocks of various kinds to produce pyrolysis oil as an alternative fuel. Pyrolysis facilities exhibit capital expenses of US$56 million for 100,000 tpa capacity, and operating costs of US$420 per tonne of treated plastic.

Alternative depolymerisation processes, such as solvent-based processes, cost around US$1,400 for PET and US$1,600 for PE and PA. Due to high infrastructure capital expenses, major CPG, chemicals and recycling players are key developers in the sector, while local municipal recyclers are likely to be downstream adopters.

Spotlight on Masdar

Masdar's interest in promoting waste management and the circular economy has resulted in several initiatives over the years.

- **Abu Dhabi Sustainability Week (ADSW):** ADSW is a global platform for accelerating the world's sustainable development. Through its initiatives and events, ADSW is a catalyst for sharing knowledge, implementing strategies and delivering solutions to drive human progress. Since 2008, ADSW has grown to include 45,000 participants from 170 countries, bringing together a unique mix of policymakers, industry specialists, technology pioneers and the next generation of sustainability leaders. In the lead up to ADSW 2020, Masdar City unveiled the world's largest mosaic made from recycled materials. This 1,015-square-meter artwork, comprising 90,500 recycled items, draws attention to the waste issue facing our society and environment at all levels.

Figure 6. Masdar City's Guinness World Record breaking recyclates mosaic. Source: Masdar City.

- **Masdar City:** Every building in Masdar City includes a collection point for four waste streams: dry recyclables (cans, bottles, paper), wet recyclables (food and organic waste), miscellaneous residuals, and hazardous materials such as batteries. Wet organic waste is composted for landscaping and agricultural use, while other streams are transported to recycling and waste-to-energy facilities.

- **Waste-to-energy: Masdar** has recently invested in two waste-to-energy projects in the UAE and Australia. Sharjah Waste to Energy is set to commence commercial operation in the third quarter of 2021. The facility will divert around 300,000 tonnes of solid waste from landfill each year – or 37.5 tonnes per hour – to supply up to 30MW of low-cost electricity to the local grid. The project will enable Sharjah to realise its zero waste-to-landfill target while supporting the UAE's 2021 goal to of diverting 75per cent of solid waste from landfills.

  East Rockingham Waste to Energy in Perth, Western Australia, is set for commercial operation in 2022. The project, currently under construction will process 300,000 tonnes per annum of non-recyclable municipal, commercial and industrial waste. Once completed, it is expected to displace 9.7 million tonnes of CO_2 over the 30-year lifespan of the project. The project will also develop and implement approved solutions for the beneficial re-use of bottom ash as an aggregate material in applications like construction and infrastructure development. In both facilities, flue gas will be extensively treated prior to atmospheric release.

ADVANCED PLASTIC RECYCLING FOR CIRCULARITY

KEY DEVELOPERS

Company	Founded (Country)	Description	Differentiator
Bulk Handling Systems (BHS)	1976 (US)	AI-sorting robotic system developer.	Turn-key system has twice the productivity of a labourer.
APK AG	2008 (Germany)	Multi-layer delamination process developer.	Near-virgin re-granulates acquired from complex mixtures; in partnership with **DSM** for further development.
Hamos	1987 (Germany)	Electrostatic separation market leader.	Claims to achieve pure sorted fraction from mixed streams.
Thahn Phu	1992 (Vietnam)	Large plastics manufacturer.	Partnered with **ExxonMobil** to produce an all-PE multi-layer packaging.
Ioniqa	2009 (Netherlands)	Glycolysis using water or ethylene glycol and magnetic particles to depolymerise waste PET to monomers.	Accepts coloured PET waste; existing 10kta plant investigates feasibility, with plans to licence technology.
Carbios	2011 (France)	Enzymatic chemical recycling.	Most effective at depolymerising polyesters like PET and PLA.
Loop Industries	2014 (Canada)	Alkaline hydrolysis using ethylene glycol and dimethyl terephthalate.	Claims to reduce solid waste by 86 percent and emissions by 63 percent.
PureCycle Technologies	2015 (US)	Uses a solvent-based system to convert mixed polypropylene waste to near-virgin grade re-granulates.	Licenced the technology from **P&G**; uses fewer steps and less energy use than pyrolysis. In the process of opening a commercial-scale facility.

Takeaway and Recommendations

Recycling initiatives and technologies are set to increase at a rapid pace in the coming years, driven by consumer demand and regulatory changes. As the plastics market becomes more heterogenous, the need for APR to handle mixed waste streams and effectively recycle plastics at scale increases.

A key theme in the industry is trade-offs as emerging technologies exhibit specific use cases. Solutions that improve plastic properties tend to add complexity to recycling, and although they promote repurposing, do not enable full circularity. Chemical recycling processes are the exception to this, and despite requiring an overhaul of existing infrastructure, represent the only method to process the diverse range of plastics on the market in a circular and sustainable manner.

Metrics	Comments
Technology value: Medium-High	APR technologies can enable higher levels of plastic reuse compared to mechanical recycling and promote a plastics circular economy.
Momentum: High	Consumers and regulations are forcing brand owners to innovate or face fines. They are now demanding more from packaging suppliers and partnering with APR start-ups, thus driving momentum.
Maturity: Low	Although most sorting and cleaning technologies are commercialised, chemical recycling processes are generally in the R&D stage with most expected to reach the market in the next five to 10 years.
Risks: Medium	Consumers are unwilling to pay anything above small premiums for greener packaging, thus brand owners must absorb APR costs. Near-term innovations rely on mechanical recycling upgrades that are only possible with effective collection schemes. In the medium term, chemical recycling could scale significantly, although reliance on feedstock access makes it difficult to pinpoint who the technology owners will be.

VEHICLE-TO-GRID TECHNOLOGIES FOR GRID SUPPORT

INTRODUCTION

With increasing adoption of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and hydrogen fuel cell electric vehicles (FCEV), grid managers are becoming increasingly worried about supplying electricity to these vehicles without overtaxing already aging grid infrastructure. As a solution, electric vehicle car manufactures, such as **Nissan**, and utility companies, including **Enel**, propose a vehicle-to-grid (V2G) strategy. In this model, electric vehicles (EVs) are not only modes of transportation, but also act as small-scale distributed power plants. The EVs would communicate with the power grid and either return electricity to the grid or throttle their charging rate depending on electricity demand from the grid. A 2015 study from the International Journal of Automotive Technology claims that V2G users can generate an annual profit of between US$300 to US$450. Another study by **Nissan** in Denmark, where frequency regulation prices are high, found that operators of its V2G electric vans can earn up to €1,300 annually.

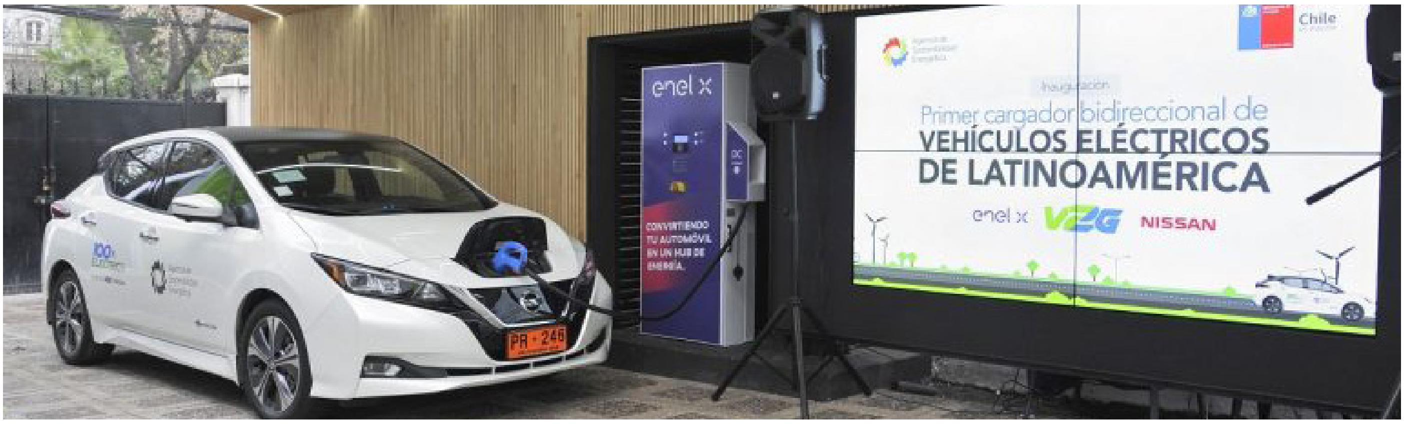

Figure 1. Nissan LEAF charging and discharging electricity at a V2G power station.
Source: Nissan Motor Corporation

Unique selling proposition

The primary applications of V2G technology are peak load levelling/load following, frequency regulation, and as backup power. For peak load levelling, EVs store power during periods of low electricity demand (i.e. during the night) and deliver it back to the grid during periods of high demand (i.e. throughout the day). By using the vehicle's battery as an energy storage system, direct electricity generation requirements during peak electricity demand is reduced. For frequency regulation, the EV battery helps regulate the grid's frequency control system.
This is especially critical in grids with a high share of intermittent renewable power, such as like solar or wind.

To help even out electricity supply, prevent the grid from being overloaded, or avoid curtailment, energy storage systems, like those from a V2G EV, would help improve this challenge. Furthermore, due to improvements in energy density, EVs are now capable of storing >70 kWh on one charge, which is around double an average home's daily energy demand. Therefore, in times of need, an EV can act as an emergency power source for a family for a few days.

Technology

V2G systems need bidirectional chargers and V2G aggregation and management control software to be technologically feasible.

Bidirectional chargers

EV charging stations today use a unidirectional charger that allows the vehicle to charge by connecting to the grid, but not the reverse. However, a V2G system needs to both send and receive current, making bidirectional chargers a must. Similarly, EVs require battery management controls that communicate with the charging station's control unit. This allows appropriate amounts of current to charge and discharge the battery during V2G connection.

As of 2019, **Nissan**'s LEAF was the only EV on the market with bidirectional charging capabilities. **Volkswagen**, **Honda** and **BMW** are all developing capabilities in bidirectional charging.
Honda has a partnership with Swiss firm **EVTec** and **BMW** has joined a consortium with transmission and distribution system operators. Meanwhile, **Fermata Energy** is one of the leading players in bidirectional charging stations, with **Delta** and **Hitachi** following suit. In 2018, **Fermata Energy** entered a partnership with **Nissan** to test its stations.

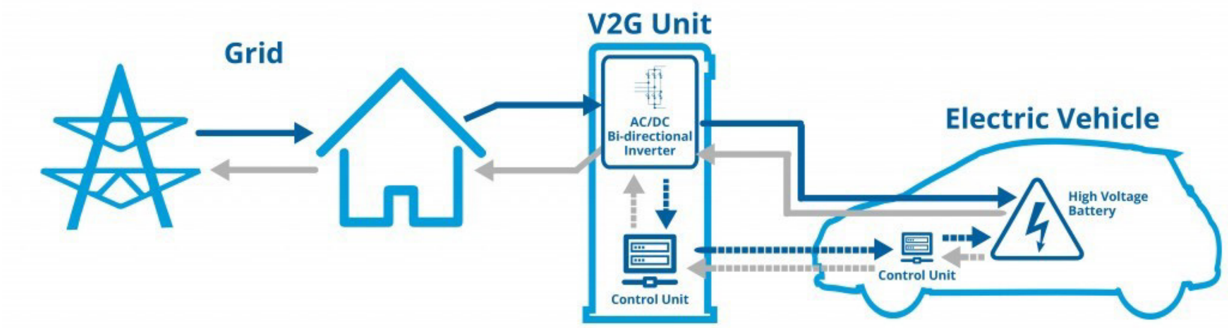

Figure 2. Schematic of a bidirectional charging station.
Source: Cenex

V2G aggregation and management control software

The primary role of V2G aggregation and management control software is to help V2G EVs communicate with a "virtual storage network" and establish when it is best to charge and discharge the vehicle's battery, specifically in response to requests from the power grid operator. The software will also help control charge and discharge speeds.

Nuvve, a California start-up focused on V2G management control software, is a leading player in Delaware and Denmark and is expanding to other countries such as Japan, France, the UK, and Belgium. **Greenlots,** another developer, operates on a technology licensing model and offers grid balancing software to utilities and even helps to install V2G technology into charging stations. **Shell** recently acquired **Greenlots** in January 2019.

Challenges

Battery life

A key challenge of V2G technology is the stress continual charging and discharging has on commercial lithium-ion EV batteries, which typically have a life of 1,500-2,000 cycles. However, Tesla's EVs have been outperforming industry averages and now claims it is developing a battery with roughly double this cycle life. Initial studies showed that battery degradation from V2G charging and discharging could reduce battery lifetime by up to five years. Since batteries account for a third of an EV's cost (upwards of US$10,000) and ownership of battery replacement liability is unclear, V2G participation is still economically risky without "smart" V2G control software that can also optimise battery life.

However, for applications such as frequency regulation, where the battery is charged/discharged at 50 per cent of capacity, pilot projects show that impact on battery degradation is minimal. As a result, **Nissan** was one of the first automotive OEMs to state that partaking in a V2G system will not void the warranty on their vehicle's battery.

Efficiency loss

Most EVs use lithium-ion batteries with a high round-trip efficiency of 90 percent. This depends on factors such as charge rate, state of charge of the battery, temperature and, most importantly, battery system components like inverters. A study in 2018 found round-trip efficiencies of V2G technology to range between 53 percent and 62 percent. Studies on the economic viability of V2G typically ignore efficiency losses, putting a further burden on the financial claims made by V2G proponents.

Vehicle mileage

Another limitation of V2G technology is the charging software's inability to anticipate electricity supply or demand from the power grid. Without robust algorithms and controls, V2G may over-deplete vehicle charge, preventing the owner from using the car for unplanned transportation.

Regulations

In many countries, such as Germany, the Netherlands and Denmark, V2G providers may be subject to levies on both energy generation and consumption, since storage is not regulated separately. In the UK, the regulator Ofgem is implementing a formal definition of energy storage to the regulatory framework that addresses this issue.

Innovations to Watch

- **Smart charging:** Charging and discharging batteries too rapidly or above acceptable capacity can shorten battery life. Smart charging algorithms that anticipate power grid needs and accordingly accelerate or decelerate the charge rate would be a solution to this challenge. A 2017 study conducted by the **University of Warwick** and **Jaguar** demonstrated that by using a smart grid algorithm, a V2G EV's battery degradation can be reduced by up to 9.1 percent, providing more favourable economics to consumers.
- **Power electronic unit (PEU)/transformer design:** Novel PEU and transformer designs can increase the roundtrip efficiency of electricity from the grid to the vehicle and back to the grid. Current estimates for V2G EV roundtrip efficiencies are rather low at around 60 percent at typical charge/discharge rates. Of the 40 percent efficiency loss, the PEU unit accounts for 25 percent and transformers account for 10 percent. Recent research shows that with appropriate designs, PEUs can achieve up to 95 percent efficiency during discharge. Similarly, with advancements in transformer implementation, researchers estimate the roundtrip efficiency can be increased by up to 70 percent.

VEHICLE-TO-GRID TECHNOLOGIES FOR GRID SUPPORT

Component	AC current (A)	Percentage loss (%)	
		Charging	Discharging
EV battery	10	0.64	0.64
	40	1.69	1.91
EV PEU	10	6.28	16.67
	40	5.77	19.23
EVSE	10	0.10	1.42
	~40	0.29	1.39
Breakers	10	0.00	2.80
	~40	1.30	0.60
Transformer	10	10.20	14.60
	~40	3.33	6.65
Total	10	17.22	36.13
	40	12.38	29.78

Figure 3. Distribution of energy efficiency losses in a V2G system.
Source: Elpiniki et. al. (2017)

Commercial aspects

The adoption of EVs has grown over the past few years from 120,000 units sold in the US in 2014 to 400,000 units sold in 2019 – equivalent to a compound annual growth rate (CAGR) of 27 percent. By 2025, this will translate to 1.6 million EVs sold in the US alone. Accounting for the average EV in the US to hold a capacity of 65kWh, approximately 104GWh worth of energy storage would be available on the road. This is around 60 times the total installed utility-scale battery-based energy storage systems in the US between 2003 and 2018. Tapping into even a small portion of this energy storage market would enable utilities to save significant amounts of money. For example, a study from Germany estimates that upgrading grid infrastructure would cost 10x more than implementing V2G solutions to handle additional demand. V2G load shifting is estimated at over US$1 billion in addressable market in California alone.

As of January 2019, there have been over 50 V2G pilot projects conducted throughout the world, where **Renault**, **Nissan** and **Mitsubishi** were key participants, and the US, the Netherlands, the UK, and Japan were leading countries. **CHAdeMO**, the organisation responsible for standardising EV fast charging, reported that V2G systems show promise in locations where 1) there is a surplus of solar capacity, 2) markets have high peak pricing or charges, and 3) long energy duration is needed.

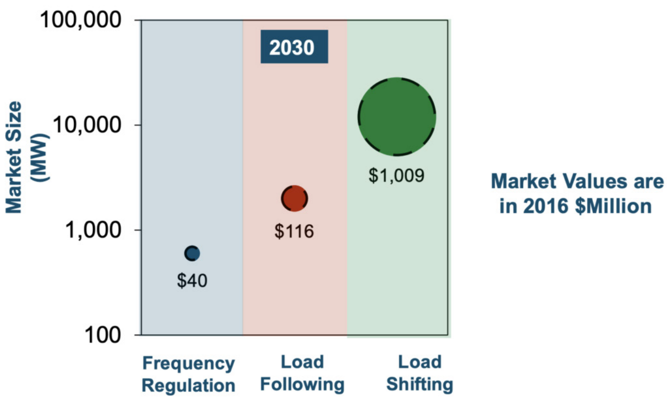

Figure 4. Approximate market sizes for load shifting applications in California.
Source: Smart Electric Power Alliance

Spotlight on Masdar

In October 2019, **Masdar** became the first commercial investor in the UK government's £400 million Charging Infrastructure Investment Fund (CIIF), investing a total of £35 million. The fund's goal is to "catalyse the roll-out of electric vehicle charging infrastructure that is required to support the electrification of vehicles". The fund aims to add 3,000 new charging stations by 2024, more than doubling the UK's current electric vehicle charging infrastructure and addressing consumer fears about being stranded with no access to a charging station.

Since **Masdar**'s investment, the CIIF has invested in **InstaVolt**, a start-up founded in 2016 that develops, installs and operates rapid electric vehicle charging stations throughout the UK. In July 2019, **InstaVolt** began construction of its 400th charging station. While this activity is unlikely to catalyse domestic V2G development due to poor economics, buildout of a robust charging infrastructure will help move the UK closer to its ambitious net-zero GHG emissions target by 2050.

VEHICLE-TO-GRID TECHNOLOGIES FOR GRID SUPPORT

KEY DEVELOPERS

Company	Founded (country)	Description	Differentiator
Nissan	1933 (Japan)	Automotive OEM.	**Nissan** is the only company with a V2G compatible EV on the market.
Honda	1948 (Japan)	Automotive OEM.	Leading developer of V2G charging stations for home and public with fast-charging capabilities.
Tokyo Electric Power Company (TEPCO)	1951 (Japan)	Japanese electric utility holding company.	One of few utility companies heavily involved in V2G pilot projects. Developing V2G with partners **Mitsubishi Motors**, **Hitachi** and **Shizuoka Gas** with support from the Japanese government.
Engie	2008 (France)	French multinational electric utility company.	One of few utility companies heavily involved in V2G pilot projects. Currently developing behind-the-meter energy storage for Vehicle-to-Building configuration in partnership with **Mitsubishi** and **Hitachi**.
Nuvve	2010 (US)	Develops high-powered, bidirectional charging stations for V2G systems as well as software for V2G EV aggregation and power control.	One of the leading players in V2G EV aggregation and power control software solutions. Has participated in many pilot projects through the US and Denmark, has partnered with **Nissan** and is currently expanding to other European countries like the UK.
Greenlots	2008 (US)	Subsidiary of the **Shell Group**; develops software for V2G EV charging/discharging optimisation and grid balancing.	Participated in many EV charging programs throughout the US including California, Illinois, Massachusetts, and several others.
Fermata Energy	2013 (US)	Energy technology company developing V2G charging stations	As of March 2020, the only company to receive the UL certification for a V2G charging system.

Takeaway and Recommendations

The rise in EV adoption is increasing the strain on energy generation assets and the grid. V2G technology gives utilities flexibility to not only meet this demand, but also to address challenges such as frequency regulation and load shifting. As such, EV developers are beginning to develop V2G compatible vehicles to enable this flexibility and unlock new streams of revenue for consumers. Start-ups are also participating in the space, developing bidirectional charging stations as well as the software needed to control and regulate charging protocols for EVs. However, while numerous pilot projects have been conducted, mass consumer adoption still remains a challenge. V2G proponents still need to convince EV owners that the economic benefits will outweigh battery replacement costs. Business cases are still unclear for cities and business owners to invest in building onsite EV charging stations. In the near term, V2G is best suited to deliver grid services such as frequency regulation that do not overtax the lithium-ion battery. V2G solutions are likely to see more widespread adoption as batteries become more robust to rapid charge/discharge, improve cycle life, and as flexible algorithms and controls become widely available.

Metrics	Comments
Technology value: Medium	V2G technology has potential to enable grid-scale utility providers to access 160GWh of energy storage in the US by 2025. This would minimise the need to immediately upgrade grid infrastructure or add grid-scale energy storage, which are capitally intensive undertakings.
Momentum: Medium	Many major OEMs are already participating in **V2G**, including **Nissan**, **VW**, **Honda**, and others. Many start-ups are now piloting V2G compatible charging stations and control software.
Maturity: Medium	There are at least 50 projects on V2G technology that have been implemented globally. **Nissan** already has a V2G compatible vehicle on the market; others are likely to follow suit in the near term.
Risks: Medium	The business case for V2G is still unclear, as liabilities and payback schemes are as yet uncertain. Technologies, such as smart controls, will help unlock applications and dampen battery degradation, but limited availability of EV charging infrastructure still limits potential for V2G deployment today.

NEWS UPDATES

Iberdrola's diversified portfolio returns profits amidst low oil demand

Iberdrola has reported a 5.3 per cent increase in net profit for Q1 2020, driven by continued investment in digital tools, energy networks and renewables. The company has already commissioned 1.2 GW of renewables and plans to add US$10.7 billion in projects this year, recently announcing its first floating wind project and long-term wind strategy, which includes large-scale installations in the US and Scotland. This serves as a valuable example of how renewables and innovation can increase an energy company's resilience while driving profits.

Solar module manufacturers unveil 500W panels

Risen Energy and **Trina Solar** have both launched a 500W PV module made up of fifty monocrystalline Si 210mm cells. These 'cut' cells are reduced in size, lowering currents and resistive losses, increasing density, and ultimately improving module performance, durability, and active area per solar cell. Higher power output reduces balance of system and handling costs by lowering number of modules required. Developers also claim the cell design can withstand high output currents that usually cause cracking.

Siemens and Uniper partner to decarbonise power generation

The partnership will target sector coupling and decarbonisation of power generation using blue and green hydrogen. Although green hydrogen is inefficient today, it can find a use case in avoiding stranded thermal power generation assets. The announcement highlights the role of hydrogen in existing gas turbines and gas storage facilities, with further mention of the potential role in coal power plants. Uniper is planning to close or convert its German coal-fired power plants by 2025 to reach climate-neutral power generation by 2035.

Shell joins growing list of oil majors pledging net-zero emissions by 2050

Shell has announced its ambition to achieve net-zero emissions by 2050 or sooner, making it one of the last European oil majors to join the decarbonisation race. In line with its peers, **Shell** plans to incorporate Scope 1, 2, and 3 level emissions to address life-cycle emissions. The company will rely on close collaboration with customers to help it decarbonise. While this approach may help drive efforts, it is unclear who will be responsible for end-use emissions.

General Electric developing wind and PV inverters for frequency and voltage response

Asynchronous wind and solar generation continue to be a key driver of energy storage. **GE**'s project, funded by a US$4.2 million grant from the US Department of Energy, aims to add controls to its **GE** LV5 inverter – used in 26GW of projects globally – that enable renewables installations to provide the services of a synchronous generating asset. If successful, the development can allow energy storage assets to focus on their intended purpose of shifting large amounts of energy.

TECHNOLOGY BREAKTHROUGHS

Researchers unveil 47.1% efficiency solar cell

The researchers at NREL have developed a six-junction tandem cell based on various layers of semiconductors made from elements such as gallium arsenide or indium phosphide. An efficiency of 39.2 percent was reported at standard illumination, and the maximum of 47.1 per cent at 143 times the concentration of light – achieved by depositing a concentrator cell on top of the device. The combination of various cells and light concentrations enables a wider utilisation of the solar spectrum in a lower active area. However, these devices are extremely complex to design, and the scarcity of these elements means that costs are likely to restrict their use to niche applications like satellites.

TOPICS FOR NEXT EDITION

Combined heat and power for sustainability

Combined heat and power (CHP) – or cogeneration – systems recover exhaust heat that would normally be lost from electricity production. The systems then use this heat for space heating and cooling, or industrial processes. In this way, the overall system efficiency can increase from around 30 percent in steam turbines to more than 80 percent. Cogeneration can also make better use of renewable energy technologies based on biomass, concentrated solar power and geothermal energy by using them to produce both heat and electricity. As distributed energy resources that couple power and heat production, CHP systems also offer increased grid flexibility and control over fuel choice, while having the potential to provide grid services. However, the integration of CHP systems represents a significant challenge to overcome to realise attractive ROIs that drive adoption.

Distributed ledgers and blockchain in the power industry

The energy grid of the future will comprise a large proportion of decentralised renewable power generation assets. In this scenario, energy is generated by both large utilities and small-scale "prosumers" that are responsible for significant portions of overall grid supply and demand. Alongside energy storage, new platforms are required to facilitate transactions and communication between this network of numerous microgrids as they dynamically respond and manage energy and generate large volumes of data in the process. The blockchain, and particularly distributed ledgers, can increase efficiency by removing intermediaries to enable a heterogeneous network to effectively respond to grid demand, provide ancillary services, supply power and trade renewable energy without long-term power purchasing agreements (PPAs).

Supercapacitors for high power applications

Unlike energy-dense lithium-ion batteries, supercapacitors prioritise high power density and high cycle life. This lends itself to applications that require fast charging and power regulation, such as regenerative braking. Despite this, supercapacitors have struggled to gain market traction over the past few decades as they are often compared to lithium-ion as most applications demand high energy density. To alleviate this challenge, new system designs include a combination of supercapacitor + battery to add fast charging capabilities to existing battery systems. This is particularly helpful for passenger EVs, which prioritise both the mileage of the vehicle as well as fast charging capabilities. As lithium batteries improve, this hybrid approach will open up new possibilities for applications requiring both high energy density and high power.

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