Challenges and Opportunities for Vehicle Photovoltaics

DATE: July 14, 2022
SUBJECT: Request for Information (RFI)

Description

The U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Solar Energy Technologies Office (SETO) and Vehicle Technologies Office (VTO) are requesting information on technical and commercial challenges and opportunities for vehicle photovoltaic systems.

Background

The term (field of) vehicle-integrated photovoltaics (VIPV) designates the mechanical, electrical and design-technical integration of photovoltaic modules into vehicles.[1] The photovoltaic (PV) modules integrate seamlessly into the vehicle exterior and electric system architecture to supply power to on-board electric loads or batteries. VIPV modules serve dual functionality by generating electric energy while replacing other structural parts of the vehicle, like the roof, the hood, the doors, the windows, the windshield, the sunroof, or other glass components. In simpler cases, referred to as vehicle-added or attached PV (VAPV), more traditional individual PV modules are attached to the existing vehicle structure serving only the energy generation role.

The first solar-powered car, the Sunmobile, was introduced in 1955 by General Motors, as a 15-inch-long model car.[2] Over the years, solar vehicle prototypes have been part of various automotive races and competitions, resulting in continuous technological improvements.[3] Currently, solar vehicles — electric vehicles integrated with solar panels — have started gaining traction and the global solar vehicle market is projected to grow at a compound annual growth rate of 36.4% from 2022 to 2030 (107,380 units by 2030).[4] It is also reported that the global vehicle-integrated solar panels market is expected to witness a similar growth rate of 29% over

[1] Fraunhofer ISE. "Vehicle-Integrated Photovoltaics." https://www.ise.fraunhofer.de/en/key-topics/integrated-photovoltaics/vehicle-integrated-photovoltaics-vipv.html (accessed May 2022).
[2] https://en.wikipedia.org/wiki/Sunmobile (accessed June 2022).
[3] European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper – Vehicle-integrated Photovoltaics as a core source for electricity in road transport. https://etip-pv.eu/publications/etip-pv-publications/download/vehicle-integrated-photovoltaics-vipv-as-a-core-so (accessed May 2022).
[4] https://www.marketsandmarkets.com/Market-Reports/solar-vehicle-market-70646574.html (accessed June 2022).

the next seven years.[5] The technical potential of VIPV in Germany is estimated by the Fraunhofer Institute for Solar Energy Systems (ISE) to be at least 55 GWp.[6]

VIPV and VAPV have the potential to represent a competitive value proposition in various transportation sectors. Integrating solar generation directly into the vehicle could increase the performance of vehicles, in terms of range, or displace some battery capacity, thus improving the vehicle's carbon dioxide (CO_2) balance. This is especially true for electric vehicles where PV systems can provide an additional source for battery charging and contribute directly to the vehicle propulsion and other vehicle loads. However, even for non-electric vehicles, PV systems could be utilized to supply power to various auxiliary electric loads and functions, therefore reducing fuel consumption. This could be of high value especially in more specialized commercial vehicles and applications, like refrigeration trucks. Electrical integration could be quite seamless as vehicles are primarily direct current (DC) electrical systems and many of the vehicle loads are DC powered. This would reduce inefficiencies that result from converting the DC electricity generated by the solar modules into alternating current (AC), as it is done by the more traditional solar systems. DC to AC conversion could only take place where needed by the specific loads (e.g., the traction inverter of electric vehicles).

Some of the potential key advantages of VIPV and VAPV systems are:[7]

- Increased range and availability of on-the-road power
- Reduced load on the electricity grid and the charging infrastructure
- Increased cost savings for charging electricity
- Reduced CO_2 emissions in the transportation sector
- Key thermal, security, and non-powered system applications

Some of the key challenges identified for VIPV systems could be:[8]

- New materials and production processes compared to conventional module construction
- Different types of modules for the specific application areas, requiring individualized production
- Requirement for highest efficiency values relative to surface area
- Integration challenges (structural or electrical)
- Operation and maintenance (O&M) considerations

5 https://www.marketwatch.com/press-release/global-vehicle-integrated-solar-panels-market-market-size-industry-insights-major-key-players-and-current-trends-analysis-and-forecast-2022-2031-2022-04-28?mod=search_headline (accessed June 2022).
6 Fraunhofer ISE. "Vehicle-Integrated Photovoltaics."
7 Fraunhofer ISE. "Vehicle-Integrated Photovoltaics."
8 Fraunhofer ISE. "Vehicle-Integrated Photovoltaics."

Photovoltaic systems on vehicles can be categorized in different ways depending on the level of integration between the solar and vehicle components, the functionality of the PV system, and the transportation segment they serve. PV systems could be "stick-on" PV modules that assist in specific functions; PV modules attached-to-vehicle that provide power for a specific functionality (e.g. refrigeration in refrigerated trucks); or fully integrated PV systems that comprise an energy source for the entire vehicle while also serving a structural role in the vehicle construction.

Typical transportation segments include:

- **Passenger vehicles** – Includes personal vehicles, such as cars, SUVs, pick-up trucks, etc.
- **Lightweight utility vehicles** – Includes small delivery trucks or passenger vans as well as more specialized small-scale vehicles, such as forklifts, golf cars, baggage carriers, construction and agricultural vehicles, etc.
- **Medium- and Heavy-duty utility vehicles** – Includes larger trucks, buses, construction, and agricultural vehicles.
- **Recreational vehicles** – Includes caravans and mobile homes.
- **Trains/Trams** – Includes passenger and freight railroad vehicles.
- **Marine vehicles** – Includes passenger/cargo ships, ferries, and other recreational vessels.
- **Aerial vehicles** – Includes aircraft and drones.

PV solutions have been considered and investigated for all the above segments and various implementation exists either as commercial products or as R&D prototypes.[9] Many of these segments provide greater potential opportunities for PV integration compared to others but are also associated with specific challenges as discussed next.

Solar passenger vehicles: Increased driving range is a possible advantage that PV systems could provide to passenger vehicles. The aesthetic expectations on PV integration into the vehicle design are especially high for passenger vehicles. Curved surfaces are quite common on such vehicles, and this adds complexity and requirements for PV system design. In addition, space limitations allow for limited surface areas where PV could be integrated into the vehicle design and consequently for limited PV capacity. The first commercial models of solar passenger cars that attracted wide public attention were models of plug-in hybrids equipped with solar roofs.[10] Typical examples of solar-electric cars include the Audi e-Tron Quattro,[11] the Toyota Prius Plug-

[9] Benjamin Commault, et al. "Overview and Perspectives for Vehicle-Integrated Photovoltaics." Multidisciplinary Digital Publishing Institute (MDPI), Applied Sciences, 2021, 11(24), 11598. Available online at https://doi.org/10.3390/app112411598 (accessed June 2022).

[10] European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

[11] European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

in Hybrid,[12,13] the Sono Motors Sion,[14] the Hyundai Sonata Hybrid[15] and the Hyundai Ioniq 5,[16] the Fisker Ocean,[17] the Aptera,[18] the Lightyear One,[19] the Mercedes-Benz Vision EQXX,[20,21] and a few other more specialized ones.[22] Several other examples have been reported in literature, mostly in the form of research prototypes.[23] All the above examples employ PV integration on the vehicles roof, while some of them also integrate PV at other parts of the vehicles, such as the hood or the doors. Bidirectional charging technology could also be optionally provided, allowing for vehicle-to-grid (V2G) or vehicle-to home (V2H) services thus feeding the grid or the home with solar power.

Solar Medium- and Heavy-Duty utility vehicles: Medium- and heavy-duty utility vehicles, e.g. larger trucks, vans, and buses, show high potential for VIPV and VAPV. The available area for installation on these vehicles is usually large, flat, and often horizontal or vertical, which makes the PV system design and installation less challenging. In addition, the energy generated by the PV modules can be used not only for propulsion but also for on-board auxiliary services, such as air-conditioning or for refrigeration systems. According to estimates from Sono Motors[24] PV integration into buses could result in up to 22.1 kWh daily energy yields for a 12m (40ft) electric bus or 1,800 liters (475 gallons) of annual fuel savings for a similar diesel bus. For light duty electric vans, solar integration on the roof and sides of the vehicle could add up to 117km of additional range per day resulting in up to 117% of energy cost savings and even potential independence from charging infrastructure. For utility vehicles particularly lightweight PV modules are needed to avoid restricting the load capacity. An additional challenge is that the benefits strongly depend on the technology used, the specific driving patterns, the geographic

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12 European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.
13 https://global.toyota/en/newsroom/corporate/28787347.html (accessed June 2022).
14 Driven by the Sun | Sono Motors – https://website.sonomotors.com/ (accessed June 2022).
15 2022 Sonata Hybrid | Sedan Overview | Hyundai USA – https://www.hyundaiusa.com/us/en/vehicles/sonata-hybrid (accessed June 2022).
16 Interesting Engineering (2021) – https://interestingengineering.com/hyundai-unveils-charger-on-wheels-ioniq-5-with-solar-panel-roof (accessed June 2022).
17 Fisker Ocean | Fisker Inc. – https://www.fiskerinc.com/ocean (accessed June 2022).
18 Aptera Motors – https://aptera.us/ (accessed June 2022).
19 Lightyear - Solar Electric Vehicle – https://lightyear.one/ (accessed June 2022).
20 PV Magazine (2022) – https://www.pv-magazine.com/2022/01/05/mercedes-newest-electric-car-comes-with-thin-film-solar-cells-on-the-roof/ (accessed June 2022).
21 Interesting Engineering (2022) – https://interestingengineering.com/the-mercedes-benz-eqxx-is-a-620-mile-range-solar-roof-ev (accessed June 2022).
22 Interesting Engineering (2022) – https://interestingengineering.com/eight-electric-vehicles-2022-solar-roofs (accessed June 2022).
23 B. Commault, et al. (2021).
24 Sono Motors – https://sonomotors.com/en/solar-integration/ (assessed June 2022).

location, and the solar irradiance, making it difficult to easily quantify the performance.[25] A detailed use case study can be found in the testing and analysis by Robby Peibst, et al.[26] Several recent proof-of-concept projects of PV systems on trucks have been reported in the literature.[27] Within this market segment, the transport refrigeration units (TRUs) could have a substantial potential for VIPV/VAPV in the U.S. Key benefits for solar powered TRU could include cost saving from less fuel consumption, lower emissions, lower maintenance due to less load on the vehicle engine, less noise pollution, and separation of cooling system from the vehicle engine resulting in better reliability.[28] In Europe, Sono Motors has recently patterned with CHEREAU to enter the market for solar-powered refrigerated trailers.[29] According to Sono Motors estimates, solar integration on the roof and sides of larger refrigerated trucks and trailers could cover up to the total energy demand to run the refrigeration unit for a day, under peak solar conditions, and the yearly average of energy earning could be approximately 50% of the annual energy demand.[30] There are over 500,000 refrigerated trucks operating in the U.S. alone[31] and an estimated over 117,000 refrigerated vehicles sold in the U.S. each year (2016), 77,000 trailers and 40,000 trucks/vans.[32] The 2021 EPA Diesel Emissions Reduction Act (DERA) pays up to 45% of the costs to replace diesel powered refrigeration with zero emission alternatives.[33] The recent California Executive Order calls for elimination of new internal combustion passenger vehicles by 2035.[34,35] California will require automakers to sell more electric trucks starting in 2024 and by 2045 all new trucks sold in the state should be zero-emissions.[36] In addition, the California Air Resources Board (CARB) has approved amendments to its current rule for TRUs operating in the state, which will require a variety of actions designed to reduce the pollution these units produce, and accelerate their transition to zero-emission technologies.[37]

Solar recreational vehicles: Recreational vehicles (RVs) present a large opportunity for PV for the U.S. market. According to the RV Industry Association the total RV shipments for 2021 ended with a record of over 600,000 wholesale shipments, surpassing the 2017 record total of

[25] European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

[26] Robby Peibst, et al. "Demonstration of Feeding Vehicle-Integrated Photovoltaic-Converted Energy into the High-Voltage On-Board Network of Practical Light Commercial Vehicles for Range Extension." Solar RRL, 2021, 2100516. Available online at https://doi.org/10.1002/solr.202100516 (accessed May 2022).

[27] B. Commault, et al. (2021).

[28] Solar Powered Trucks. Available online: https://tsscgroup.com/products-and-services/truck-bodies-semi-trailers/solarpowered-trucks/ (accessed June 2022).

[29] Sono Motors – https://sonomotors.com/en/press/press-releases/sono-motors-and-chereau-sign-contract/ (accessed June 2022).

[30] Sono Motors – https://sonomotors.com/en/solar-integration/ (assessed June 2022).

[31] https://www.shipabco.com/10 fast facts refrigerated trucking/ (accessed May 2022).

[32] https://askwonder.com/research/refrigerated-vehicles-sold-usa-year-9qytyzpa2 (accessed May 2022).

[33] https://www.epa.gov/sites/default/files/2021-01/documents/420f21003.pdf (accessed May 2022).

[34] https://ww2.arb.ca.gov/resources/fact-sheets/governor-newsoms-zero-emission-2035-executive-order-n-79-20 (accessed May 2022).

[35] https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/ (accessed May 2022).

[36] https://www.npr.org/2020/06/26/883634480/californias-landmark-electric-truck-rule-targets-diesel-death-zone (accessed May 2022).

[37] https://ww2.arb.ca.gov/news/carb-approves-new-requirements-further-reduce-air-pollution-transport-refrigeration-units-and (accessed May 2022).

about 505,000 shipments by 19%. This was a 39.5% increase over the approximately 430,000 units shipped in 2020.[38] There were about 11.2 million RVs owned in the U.S. in 2021.[39] Such vehicles are typically equipped with off-grid power sources and, therefore, attached PV system installation are fairly common and highly desirable by RV owners. RV PV systems provide a flexible power resource, which can be used for charging batteries, reduce or eliminate the generator use, provide emergency backup power, and with bidirectional charging technology allow for vehicle-to-grid (V2G) or vehicle-to home (V2H) services, thus feeding the grid or the home with solar power or act as energy storage system for the home.

Solar trains: The large rooftop area of trains could also provide a surface to install PV to power on-board services. Examples include Indian Railways, Byron Bay Train in Australia, and others in Europe prove the feasibility.[40,41]

Solar marine vehicles: Electrification of the maritime sector can also be an opportunity to reduce emissions of the sector. VIPV/VAPV provides be a great opportunity for ships with feasible power-to-weight ratio used for short distances. Ships could provide large surface areas for integrated PV and could also have access to unobstructed view of the sun when traveling on large water bodies, thus minimizing the impacts of shadowing. Production of solar electric ships can already be found in Europe or Asia. Barco Solar from Portugal, for example, produces solar boats with range extension of 56 km (30 nmi) under ideal weather and sailing conditions.[42] Navalt is also a producer of a variety of solar vessels in India.[43] A 100% solar-powered catamaran using flexible heterojunction solar cell modules was announced in 2021 and is being tested.[44] In the United States a first-ever solar-powered boat launched in Maine on Earth Day 2022.[45] Like in other transportation applications, VIPV in the maritime sector can be used to run lighting, air-conditioning, fridge, communications services, navigation tools (autopilot, navigation computer, radar), GPS, and charge the battery.[46]

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38 https://www.rvia.org/news-insights/rv-industry-produces-600000-rvs-2021-surpassing-previous-record-19 (accessed May 2022).

39 https://www.gorving.com/newsroom/rv-industry-association-manufacturing-statistics#:~:text=RoadSigns*%202021%20Forecast%3A&text=The%20latest%20projection%20shows%20total,end%20total%20of%20430%2C412%20units (accessed June 2022).

40 B. Commault, et al. (2021).

41 European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

42 European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

43 Navaltboats - solar electric ferry – https://navaltboats.com/ (accessed June 2022).

44 PV Magazine (2021) - https://www.pv-magazine.com/2021/05/28/solar-catamaran-100-powered-by-heterojunction-modules/#:~:text=The%20100%25%20solar%2Dpowered%20boat,by%20Russian%20manufacturer%20Hevel%20Solar (accessed June 2022).

45 https://wokq.com/historic-moment-first-ever-100-solar-powered-boat-just-launched-in-maine/ (accessed June 2022).

46 European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper.

Solar aviation: VIPV can be used to partly meet power demand on the bigger planes or provide integration opportunities for smaller electric aircraft on the shorter flights. Several cases have been investigated for unmanned aerial vehicles (UAVs) and planes, but mostly at the R&D level resulting in research prototypes and low volume production.[47] VIPV can increase flying range, enhance linger times, establish better comfort on the tarmac, and provide features for unmanned and autonomous vehicles.

Solar cell technologies are an important aspect of VIPV. Weight, size, form factor, flexibility, resistance to vibration, visual appearance, and power conversion efficiency (PCE) requirements are extremely important to improve the overall vehicle performance, durability, aesthetics, and minimize any impacts of adding PV systems on the vehicle. B. Commault, et al.[48] present some detailed information of curved, flexible, or lightweight rigid PV modules that have been adopted for various VIPV applications. Lightweight rigid modules use monocrystalline silicon cells or various thin-film devices (amorphous silicon (a-Si), Copper Indium Gallium Diselenide (CIGS), organic PV (OPV)). Crystalline Si dominates and curved modules are typically either monocrystalline silicon shingle cells (PERC, MWT, interdigitated back contact (IBC)) or heterojunction technology (HJT) cells. Flexible PV are based on a variety of technologies, primarily monocrystalline silicon IBC cells, OPV cells, CIGS or a-Si cells. Glass–glass and glass–backsheet curved PV modules are currently the most common technology in VIPV despite their higher weight. Light and rigid or curved modules present the advantage of having better potential to replace body parts of a vehicle.[49] Flexible PV modules currently represent the most active technology for new VAPV product development. Such modules and can be added to existing vehicles, like on the roof, with limited added weight and they represent one of the fastest ways to integrate photovoltaics. The efficiency of such modules is improving rapidly, and a significant development effort is targeting VIPV applications.[50]

Although significant benefits have been identified from the use of solar power in vehicles, it appears that the adoption of solar technologies by the vehicle industry is in the very early stages and rather slow. This could be attributed to a number of factors, such as:

- The technologies have not progressed in terms of solar performance, cost, or ease of integration as quickly as anticipated or to the extent desired;
- The expected benefits are not easily materialized or are uncertain and difficult to quantify;
- The cost-to-benefit ratio is not adequate to justify widespread commercialization of the technologies;

[47] B. Commault, et al. (2021).
[48] B. Commault, et al. (2021).
[49] B. Commault, et al. (2021).
[50] PV Magazine (2022) – https://www.pv-magazine.com/2022/06/06/sharp-achieves-conversion-efficiency-of-32-65-in-flexible-lightweight-solar-module/ (accessed June 2022).

- There is a lack of awareness of and/or confidence in the technology from key stakeholders, including automotive manufacturers, vehicle fleet operators, end-users, and others;
- Favorable policy landscape is not in place to support VIPV adoption;
- Some combination of the above or other factors.

This RFI is intended to identify and quantify barriers and explore key opportunities to inform future DOE/EERE strategy program development in this area.

In this RFI, the offices are primarily interested in information related to VIPV/VAPV, their functionality, and their value proposition for applications to vehicles.

For vehicle PV systems adoption to increase, it is critical to understand the extent and impact of each barrier, the opportunities to address specific barriers in the near term, and potential applied R&D program designs that could effectively address each challenge.

Purpose

The purpose of this RFI is to solicit information and feedback from a broad range of stakeholders, including industry, market experts, regulators, researchers, academia, government agencies, and other stakeholders on the current state of the VIPV/VAPV market and industry, on issues related to VIPV/VAPV technologies and markets, as well as on opportunities and barriers for VIPV/VAPV to inform strategic priorities for EERE. This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Confidential Business Information

Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery two well-marked copies: one copy of the document marked "confidential" including all the information believed to be confidential, and one copy of the document marked "non-confidential" with the information believed to be confidential deleted. Submit these documents via email, if feasible. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

Evaluation and Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

Request for Information Categories and Questions

Category 1: **State of the Industry and Key Domestic Markets**

1. What market segments or subsegments are more promising for vehicle PV systems (passenger vehicles, recreational vehicles, lightweight utility vehicles, medium- and heavy-duty utility vehicles, trucks, buses, transport refrigeration units, marine vehicle, or other)? Please elaborate why you assess certain segment(s) as more promising and how each specific segment aligns with commercialized VIPV/VAPV products?
2. What is the largest market opportunity for VIPV/VAPV, and why?
3. Are there certain products or components that could create an opportunity for domestic manufacturing?

4. Establish ways in which solar generated electricity could be used in a system to enhance vehicle performance, increase security, increase safety, provide low-cost cooling, provide benefits, or be used as an independent - dual use feature for a vehicle operator.

Category 2: **Product Requirements**

1. What vehicle PV products are available in the market?
2. What are the key product requirements for a given market segment? Please define the market segment and consider aspects such as performance, weight, lifetime, reliability (including durability, vibrations, etc.), (specific) code compliance, supply chain integration, design process integration, aesthetics, installation process, installed system costs, etc.
3. What PV cell technologies would be more appropriate for VIPV applications, e.g. traditional mono/poly-Si, IBC, HJT, a-Si, multi-junction, III-V, CIGS, OPV, other? Do different technologies align better with specific applications or market segments?
4. What are the key integration requirements and challenges with respect to structural integration, electrical systems integration (electrical wiring, energy conversion, power electronics, MPPT tracking, system controls, etc.) or other integration aspects, e.g. maintenance/service/repair?
5. What are challenges to vehicle PV integration with respect to the vehicle material performance requirements and rating metrics established by standard organizations or by end-user expectations? Such standards and metrics could relate to safety, acoustic emissions, vibrations, recycling of vehicle components, reliability/robustness/durability, longevity, functionality, cost, aesthetics, etc.
6. How well or poorly do current performance requirements and standards align with vehicle PV applications? Do current standards need to be updated or are new standards needed?
7. What requirements or other considerations exist that relate to vehicle operation, maintenance, repairs, or replacements of VIPV/VAPV systems as well as insurance?

Category 3: **Key Barriers and Perceptions**

1. What are the barriers to the adoption and commercialization of VIPV/VAPV technologies?
2. What are barriers to collaboration/partnering between solar and vehicle industries on VIPV/VAPV technologies and businesses?
3. Are there additional related barriers impeding the adoption of VIPV/VAPV technologies?

Category 4: **Research, Development, Demonstration, & Commercialization (RDD&C) Needs and Opportunities**

1. What limitations exist in current modeling of the production cost, installed system cost, and energy yields for vehicle PV technologies and systems?
2. What limitations exist in current evaluations and standardized calculations for vehicle PV systems applications with respect to vehicle performance, energy produced, and carbon emission reduction?
3. What vehicle PV technology challenges could be addressed by additional research, development, and demonstration?
4. What are the challenges to demonstrating and validating the durability and performance of vehicle PV technologies and systems?
5. What would be the key challenges for mobile solar + energy storage systems with the potential for vehicle-to-home or vehicle-to-grid operation?

Category 5: **Stakeholder Engagement Processes**

1. Where do information and knowledge gaps exist in the industry as well as regulatory agencies?
2. What stakeholder groups should be involved in conversations on VIPV/VAPV product requirements, barriers, and RDD&C needs?
3. Outside of the typical outreach mechanisms (RFIs, workshops), are there other programs or events that you would recommend to effectively engage all impacted and interested stakeholders?

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to vipv@ee.doe.gov no later than 5:00pm (ET) on August 22, 2022. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email, and no more than 8 pages in length, 12 point font, 1 inch margins. Only electronic responses will be accepted.

It is recommended that responses are directly provided to the specific topics and questions of this RFI following the layout presented in the Request for Information Categories and Questions section of this document. Please clearly identify the specific category or question you are providing information for in your submission using the numbering convention provided in the RFI to identify the answer (for example 5.1). Respondents may provide information for as many or as few topics as they wish.

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:

- Company / institution name
- Company / institution contact
- Contact's address, phone number, and e-mail address