Economic Commission for Europe

Committee on Sustainable Energy

Group of Experts on Cleaner Electricity Systems	Group of Experts on Energy Efficiency	Group of Experts on Renewable Energy
Twentieth session	**Eleventh session**	**Eleventh session**
Geneva, 16-17 September 2024	Geneva, 16-17 September 2024	Geneva, 16-17 September 2024
Item 7 of the provisional agenda	Item 8 of the provisional agenda	Item 7 of the provisional agenda

Inter-sectoral cooperation on cross-cutting issues

Integration of e-mobility into electricity system, and the impact that it has on the latter's design and operations

Introduction

1. Electric mobility (e-mobility) represents a transformative shift in the transportation sector, driven by the imperative of reducing carbon emissions and reliance on fossil fuels. Transitioning from traditional internal combustion engine vehicles to electric vehicles (EVs), is seen as both challenge and opportunity for the energy landscape. From an energy perspective, the growth of e-mobility necessitates careful management of grid infrastructure, expanded charging networks, and innovative solutions like vehicle-to-grid (V2G) technologies. These dynamics have far-reaching implications not only for transportation systems but also for power generation, transmission, and distribution, as well as consumption patterns.

2. The grid management faces a new layer of complexity with integration of EVs into the grid, increasing the strain on the grid especially during peak hours. However, it is argued that this potential burden can be transformed into a strategic advantage, as smart charging infrastructure may help optimize EVs energy usage – not only by shifting demand to off-peak hours, but also by utilizing EVs as decentralized energy storage units, offering surplus power back to the grid (V2G) particularly during peaks.

3. In addition to optimization of the grid, the success of e-mobility deployment largely depends on the development of widely available and affordable charging infrastructure and solutions, along with considerations of such aspects of location efficiency of travel destinations (which in certain instances may reduce the mobility needs), locally available grid capacity and potential for on-site renewable energy-based generation, as well as user convenience to overcome the often-existing behavioural barriers. While rural areas pose unique challenges in this regard, urban areas, motorways, and commercial centres require development of approaches to ensure seamless access to charging facilities for individual, public, and freight transport. This links buildings, industry, transport, and infrastructure through the land use.

4. As e-mobility continues to evolve, it requires a holistic and balanced approach that considers not just EVs themselves, but the broader energy ecosystem that is also experiencing a transformation towards a reduced carbon footprint, among other by embracing higher shares of intermittent and decentralized renewable energy sources. Eventually, e-mobility can potentially reshape not only the transportation sector, but also the way energy is generated, stored, and consumed, thus requiring a coordinated cross-sectoral action. These and other aspects were discussed at the "Workshop on Integration of E-Mobility into Energy System" (Geneva and online, 11 April 2024),[1] laying the groundwork for a joint assessment of the current trends in the area of e-mobility, as well as for conceptualizing the harmonized approaches to the deployment of EVs that ensure that electrification of transport is supported by the power system and its reliability performance and brings net benefits to all energy system actors.

---

[1] See: https://unece.org/info/events/event/389557

5. This document summarizes the proceedings and presents the key findings from the workshop, further serving awareness-raising and information sharing on the matter and calling for the enhanced cross-sectoral collaboration.

I. Electric vehicles in the electricity system

6. Integration of EVs into the electricity system is a complex but crucial process that involves adapting existing infrastructure and developing new technologies to accommodate the growing number of EVs. This integration not only supports the transition to cleaner transportation but also has implications for how electricity is generated, distributed, and consumed.

7. In particular, EVs add significant load to the electricity grid, especially during peak charging times. As more EVs are adopted, utilities will need to ensure the grid can handle this extra demand without compromising reliability. In this case, strategies like load shaping, shifting, and shedding are crucial to avoid peak demand spikes. For example, encouraging EV owners to charge during off-peak hours helps distribute demand more evenly across the day, reducing stress on the grid.

8. Additionally, EVs can participate in demand response programs, where they reduce or shift charging during periods of high grid demand in exchange for incentives, helping to balance electricity supply and demand. The existing grid infrastructure, particularly the distribution system, may not be capable of handling the widespread adoption of EVs, especially in areas with high penetration. Utilities will thus need to invest in upgrading substations, transformers, and distribution lines to increase capacity.

9. The development of extensive EV charging networks, including fast-charging stations, is an essential step. These stations can place substantial demand on local grids, necessitating strategic planning for their deployment. Ensuring that charging stations and EVs are interoperable with the grid and adhere to common standards is crucial for a seamless and efficient charging experience.

10. EV integration supports the broader transition to renewable energy. By charging EVs during periods of high renewable generation (like daytime solar production), excess renewable energy can be utilized rather than curtailed, improving overall grid efficiency.

11. The transition to a smart grid is crucial for integrating EVs. Smart grids can use sensors, communication technologies, and advanced control systems to manage electricity flows in real-time, enabling better coordination of EV charging and grid resources.

II. Opportunities arising from integration of e-mobility into electricity system

12. E-mobility presents numerous opportunities, which have the potential to transform both the energy and transportation sectors. For example, EVs can ensure grid flexibility and stability. They can serve as mobile energy storage units through V2G systems, which allow EVs to feed electricity back into the grid during peak demand periods. This can help balance the grid and reduce the need for additional, often carbon-intensive, power generation during times of high demand.

13. EVs and their integration with the electricity grid enable better utilization of renewable energy sources. For instance, EV charging can be synchronized with periods of high solar or wind power generation, reducing reliance on fossil fuels and supporting grid decarbonization. EV batteries can act as decentralized energy storage units that absorb surplus renewable energy during periods of low demand (like midday solar energy peaks). This stored energy can then be released back into the grid when renewable energy supply is low, such as during the night or on cloudy days. By aligning EV charging times with the availability of renewable energy (for example, charging EVs during the day when solar generation is high), EVs can help to prevent the curtailment of renewable energy, leading to greater efficiency in energy use.

14. Overall, the electrification of transportation increases electricity demand, providing utilities with new revenue sources. This demand can be managed to avoid strain on the grid while

offering significant growth for utility companies, especially through managed charging and V2G services.

15. By encouraging EV users to charge during off-peak hours, utilities can balance electricity demand throughout the day. Off-peak charging takes advantage of lower electricity rates during times when demand is low, saving money for consumers and reducing the need for utilities to invest in additional peak capacity.

16. The development of EV infrastructure, such as charging stations, battery technologies, and software platforms, also creates jobs across multiple sectors, including energy, construction, and technology. The transition to e-mobility also stimulates the automotive and manufacturing sectors.

17. With the integration of e-mobility, utilities and grid operators can use advanced data analytics and AI to better forecast electricity demand. By understanding EV charging patterns, they can more efficiently plan energy generation and distribution, improving overall grid efficiency.

18. Smart chargers can optimize charging based on grid conditions, electricity prices, and renewable energy availability. They ensure that EVs are charged during times when the grid has excess capacity or when electricity is cheapest and cleanest. This improves energy efficiency across the grid.

19. Overall, EVs, when powered by renewable energy, significantly reduce greenhouse gas emissions compared to gasoline or diesel-powered vehicles. This directly contributes to national and global climate goals aimed at reducing emissions in the transportation sector, which is one of the largest sources of pollution. The electrification of public transport systems, such as buses and trams, leads to cleaner air in urban areas, reduces reliance on fossil fuels, and cuts down on the carbon footprint of large transport fleets.

20. Transitioning to EVs overall reduces dependence on fossil fuels, particularly oil, which can be subject to volatile prices and supply disruptions. By relying more on electricity from renewable sources, countries can enhance their energy security and reduce vulnerability to international fuel market fluctuations. By integrating e-mobility with renewable energy systems, developing regions can leapfrog traditional fossil fuel-based infrastructure, leading to more sustainable development and long-term energy resilience.

III. Challenges of e-mobility integration into electricity system

21. Integrating EVs into the electricity system also presents significant challenges that need to be addressed to ensure a smooth and sustainable transition. The large-scale adoption of EVs will significantly increase electricity demand, putting pressure on existing grid infrastructure. Many grids, especially in regions where EV adoption is accelerating, may not have the capacity to handle the additional load without substantial upgrades. Charging multiple EVs in a localized area, such as a neighbourhood, can create stress on local distribution transformers and circuits, leading to power quality issues, equipment failures, or outages.

22. At the same time, grid infrastructure upgrades require long-term planning and significant investment. As EV adoption grows unpredictably, utilities will have to balance current infrastructure needs with future demands, often without clear guidance on where and when to invest.

23. The lack of widespread, reliable charging infrastructure is a major bottleneck for EV adoption in many countries. To fully integrate e-mobility, charging stations need to be deployed at a massive scale in urban areas, along highways, and in rural regions. Fast-charging stations, which are necessary for long-distance travel and fleet operations, require significant electrical infrastructure upgrades. These stations can impose large, sudden loads on the grid, complicating grid management and planning. At the same time, not all communities have equal access to charging infrastructure, particularly lower-income and rural areas. This creates disparities in EV adoption and could reinforce existing inequalities in access to cleaner mobility.

24. Additionally, the uncontrolled or unmanaged EV charging, especially during peak electricity demand periods, can exacerbate peak loads on the grid, leading to instability and the need for additional generation capacity. If EV charging coincides with peak household energy use (e.g., evening hours), it can strain grid resources. In this case, encouraging off-peak charging (for example, overnight charging) is essential for reducing grid stress, but it requires effective price signals (special tariffs) and consumer education.

25. Charging EVs with renewable energy can be challenging due to the intermittent nature of solar and wind power. And to align EV charging with renewable energy generation, the advanced grid management tools and energy storage solutions are needed. Deploying these systems at scale requires significant investment and technical coordination.

26. Technical complexity is also seen with V2G technology. While it holds promise for enhancing grid flexibility, its implementation is still very complex. Bi-directional charging requires specialized infrastructure, hardware, and software, and EVs capabilities for it. Using EVs for V2G services, where the battery is frequently charged and discharged, may also lead to faster battery degradation, reducing the vehicle's overall lifespan and efficiency. And consumers may be reluctant to participate in the V2G programs if battery longevity is compromised.

27. Expanding charging infrastructure and upgrading grid capacity requires substantial capital investment, which can be a deterrent for utilities and Governments. The financial burden of these upgrades may also be passed down to consumers in the form of higher electricity rates or taxes. Deciding how the costs of grid upgrades and charging infrastructure should be distributed between EV users, utilities, Governments, and general ratepayers is a complex challenge that requires careful regulatory oversight.

28. The increased connectivity of EVs to the grid, charging stations, and energy management systems creates potential vulnerabilities to cyberattacks. A breach in EV charging networks or V2G systems could disrupt both the transportation and energy sectors. EVs collect and share significant amounts of data related to charging patterns, driving behaviour, and location. Protecting this data from misuse or unauthorized access is needed to maintaining consumer trust and compliance with data privacy regulations.

29. The absence of uniform technical standards for charging infrastructure, EV communication protocols, and V2G technology creates inefficiencies and interoperability issues. In many countries, regulations governing EV charging, grid interaction, and renewable energy integration are only evolving. Regulatory uncertainty can delay investment in infrastructure and create confusion among utilities, businesses, and consumers.

30. E-mobility development raises environmental and resource challenges. The production of EV batteries requires significant amounts of raw materials, such as lithium, cobalt, and nickel. These materials are often sourced in ways that raise environmental and ethical concerns, such as mining-related pollution and inappropriate labour practices. The growing number of EV batteries will eventually lead to large quantities of battery waste. Establishing efficient and sustainable recycling systems for lithium-ion batteries is critical to minimizing environmental harm and resource depletion.

IV. Usage patterns

31. Despite advances in EV technology, many consumers still worrying that they will not have sufficient battery capacity to reach their destination. Most EV users also do not deplete their entire battery capacity on a daily basis. The prevalent use of AC charging for regular daily charging needs, with fast-charging solutions like Ionity and other providers primarily utilized for longer trips. The insights aligned with the trend of consumers increasingly seeking bidirectional charging options and dynamic off-peak charging solutions to optimize their EV charging experience.

32. The growing interest among EV users in bidirectional charging and off-peak charging solutions are seen from the examples like the offers from Octopus company in the UK, which

provide green energy options at lower prices during specific timeframes. The suggestion for a centralized and standardized solution to manage high-demand devices like EVs and heat pump systems, leveraging predictive energy production data and utilizing energy stored in car batteries during non-peak times, is a strategic approach to balancing peak electricity demands and optimizing energy use efficiently.

33. Additionally, the connectivity of modern EVs to backend systems through services like eCall underscores the potential for establishing seamless communication channels between centralized control systems, EVs, and energy production sources. By leveraging this connectivity and establishing standardized protocols for communication and energy management, there is an opportunity to create smart solutions that can dynamically adjust energy usage based on real-time grid conditions, production forecasts, and consumer preferences.

34. Enhancing coordination and communication between centralized energy management systems, EVs, and energy production sources is a crucial step in addressing the increasing demand for electricity and ensuring efficient utilization of resources. By establishing standardized frameworks and interoperable systems, the potential exists to create a more reliable and sustainable energy ecosystem that optimizes energy use, reduces peak demand, and integrates renewable energy sources effectively.

35. For example, Norway's distribution system, largely powered by electricity for heating and household needs, provides a solid foundation for EV charging infrastructure. The installation of high-power charging stations, such as those offering 22 kilowatts on three-phase systems, can strain weak distribution systems and require careful planning to avoid overload issues.

36. The increasing demand for power from EV chargers, both to meet current needs and future expansion plans, presents challenges for Distribution System Operators (DSOs) in terms of capacity planning and infrastructure development. DSOs may face difficulties in fulfilling requests for high-power charging stations due to the lead time required for building new infrastructure, such as transformers and power lines, leading to delays in accommodating the desired charging capacity. In response to the demand for rapid charging infrastructure deployment, Norway is exploring solutions that can be quickly implemented and potentially relocated to adapt to changing needs.

V. Vehicle-to-grid

37. V2G opportunities are intriguing, as it has the potential to revolutionize the way energy is managed and utilized within the grid. V2G technology allows EVs to not only receive energy from the grid but also to provide energy back to the grid when needed, thereby serving as mobile energy storage units. The implementation of V2G technology is still in the early stages, with several pilot projects and research initiatives exploring its feasibility and potential benefits. Some countries have started testing V2G systems, and there are ongoing efforts to integrate EVs as grid resources in a more systematic manner.

38. V2G implementation is primarily at a pilot level, and it is still in the exploratory phase rather than widespread adoption, especially in households. Nonetheless, the potential significance of V2G in future energy management strategies, particularly in household charging and large parking areas with multiple vehicles, is foreseen.

39. The smart charging algorithms and time-of-use pricing mechanisms can already be effectively utilized by owners of EVs. By leveraging these smart charging practices, consumers can automatically optimize their charging schedules to take advantage of lower electricity prices and grid tariffs during off-peak hours, resulting in more cost-effective and grid-friendly charging habits.

40. Furthermore, a significant portion of charging can be carried out using AC chargers at home or other locations underscores the potential impact of implementing smart charging strategies on a broader scale. By ensuring that consumers are charging their EVs in a smart and efficient

manner, there is a substantial opportunity to enhance grid reliability, reduce peak demand, and promote the integration of renewable energy sources.

41. While V2G technology holds promise for providing grid support and flexibility, the focus on optimizing current charging practices through smart algorithms and automated solutions aligns with the idea of addressing the low-hanging fruit first before scaling up to more advanced technologies like V2G. By encouraging widespread adoption of smart charging practices and integrating them seamlessly into existing infrastructure, the transition to a more sustainable and grid-responsive charging ecosystem can be achieved effectively.

42. There is also a foundational importance of hardware compatibility and standardization in the development and deployment of bidirectional charging, particularly for V2G applications. The current lack of AC wall boxes supporting bidirectional charging protocols such as ISO 15118 presents a significant barrier to widespread adoption of V2G technology and a key challenge in advancing bidirectional charging infrastructure.

43. While there may be some DC wall boxes available on the market that support bidirectional charging, they are often expensive and more suitable for small companies or commercial applications with additional energy systems like PV systems and energy storage solutions. This limited availability and high cost of bidirectional charging hardware can pose obstacles for individual households looking to implement V2G technology effectively.

44. The need to establish standards not only for vehicles but also for charging appliances and smart home solutions underscores the interconnected nature of energy systems that must work harmoniously to optimize energy usage and achieve sustainable outcomes. By promoting interoperability and standardization across various components of the energy ecosystem, including EVs, charging infrastructure, home energy management systems, and renewable energy sources like PV systems, it becomes possible to create a unified and efficient energy network.

VI. Broader integration between the power sector and e-mobility

45. The potential of charging stations equipped with additional resources, such as batteries, to function as flexible assets that can provide ancillary services to the grid. The broader role that charging infrastructure can play in grid support and the importance of considering reactive power management, voltage support, and the integration of battery systems to enhance grid stability and resilience.

46. Integrating stationary batteries alongside charging stations can help reduce peak demand and provide ancillary services to the grid, such as frequency support and voltage regulation. Battery systems can respond quickly to grid events, offering flexibility to address short-term challenges and support the integration of renewable energy sources and EVs.

47. Charging stations typically consume reactive power, which can impact voltage levels in local power systems. By leveraging converter-based interfaces and advanced control strategies, charging stations can provide reactive power support to stabilize voltage levels and alleviate grid constraints. Establishing reactive power markets or incorporating reactive power requirements in charging station agreements can help optimize grid operation and mitigate voltage-related issues in distribution networks.

48. Battery systems integrated with charging stations can offer peak shaving capabilities, grid support services, and participation in the flexibility market for short-duration events. By leveraging the energy storage capacity of batteries, charging stations can enhance grid reliability, optimize energy use, and contribute to grid balancing efforts during peak demand periods or grid disturbances.

49. Collaboration of experts and exploring the opportunities for leveraging battery resources in innovative ways can lead to significant advancements in grid optimization and sustainable energy integration. This field of research work ongoing in Sweden and shared enthusiasm for exploring the possibilities offered by battery resources to enhance grid resilience and performance.

50. Exploring innovative solutions to leverage special vehicle use cases, such as school buses, as community backup energy resources. The idea of repurposing parked school buses equipped with larger batteries to provide essential services, like heating or cooling in community shelters during emergencies, demonstrates a creative and practical application of EV technology for resilience and disaster response. School buses, with their large numbers and often idle times, represent a valuable resource that can be mobilized as backup energy sources during emergencies when power outages occur. By equipping school buses with appropriately sized batteries and infrastructure, they can serve as mobile energy hubs that provide critical services to community shelters, enhancing resilience and ensuring the well-being of residents in times of crisis.

51. Tailoring the battery size of school buses to match the energy demands of community shelters and emergency facilities illustrates the importance of right-sizing energy storage solutions for specific applications. By optimizing battery capacity based on the anticipated needs of shelters for heating, cooling, or other essential services, school buses can effectively support community resilience efforts and enhance overall disaster preparedness. While the focus on school buses as community backup energy resources is a compelling example, exploring similar use cases for other specialized vehicle fleets, such as transit buses or emergency response vehicles, can further expand the potential of EVs in providing essential services during emergencies. Identifying and prioritizing specific vehicle fleets with unique capabilities, operational characteristics, and idle times can unlock opportunities for maximizing their role as decentralized energy assets for community resilience.

52. The importance of developing standardized interfaces and communication protocols for V2G technology to address existing challenges and unlock its potential benefits. Establishing such interfaces and communication standards for V2G systems can reduce deployment costs, streamline integration processes, and facilitate interoperability among different stakeholders and technologies. By defining clear technical requirements and protocols, standards can minimize uncertainties, enhance market confidence, and accelerate the adoption of V2G solutions at scale

53. While mandating specific V2G requirements may not be necessary at this stage, focusing on standardization efforts and industry alignment can create a foundation for future regulatory frameworks and market development. Collaborative initiatives to develop standards that address grid interface, data exchange, cybersecurity, and interoperability can pave the way for smoother V2G integration and regulatory compliance in the future.

54. Prioritizing the responsible scaling of V2G technologies involves understanding the potential benefits, use cases, and value propositions that these systems can offer to the grid, utilities, stakeholders, and end-users. As V2G solutions evolve, it is essential to identify specific problems that V2G can address, such as grid balancing, peak demand management, energy resilience, or emergency response, and tailor implementation strategies accordingly. Accelerating the development of V2G standards should be a primary focus to remove barriers, enhance compatibility, and promote innovation in the EV and energy sectors. Active engagement in standardization processes, collaboration with industry partners, and alignment with international best practices can drive the establishment of robust, effective standards for V2G technology.

55. The standardization group, such as IEC TC 69, and the critical role that standardized interfaces play in unlocking the potential of V2G technologies for grid integration and community benefits. The standardization of V2G interfaces and communication protocols is essential for ensuring compatibility, reliability, and interoperability with low-voltage grids, thereby minimizing grid impacts and enhancing community resilience. By establishing standardized practices, data exchange formats, and technical requirements for V2G integration, stakeholders can harness the collective resource potential of EVs to support peak shaving, renewable energy integration, and grid stability at the local level.

56. Leveraging the aggregated capacity of EV batteries through V2G technologies presents opportunities for grid operators, communities, and energy systems to access flexible storage resources, optimize energy management, and support renewable energy sources like wind power. By coordinating V2G capabilities with grid needs, energy demands, and market dynamics,

stakeholders can unlock the full value of EVs as distributed energy assets for demand response, energy balancing, and storage applications.

57. Addressing the complexity of V2G interactions, including roaming agreements, inductive charging technologies, and grid integration requirements, necessitates comprehensive standardization efforts that encompass diverse stakeholders, technologies, and use cases. Developing robust standards for V2G operation, grid interaction protocols, cybersecurity measures, and interoperability criteria is crucial for fostering market maturity, innovation, and regulatory compliance in the evolving landscape of electric vehicle charging and grid support services.

58. Standardization plays a pivotal role in shaping the future energy landscape by defining the technical specifications, communication protocols, and operational guidelines that underpin efficient V2G deployment, grid interaction, and energy transition strategies. Ongoing efforts to develop and refine standards, especially in the context of emerging technologies like V2G, highlight the complexity and importance of ensuring robust, interoperable frameworks before scaling up new initiatives.

59. The iterative nature of standard development, with subsequent rounds refining and expanding guidelines to encompass new technologies like V2G, reflects a pragmatic approach to accommodating evolving industry needs and technological advancements. By building upon existing standards and integrating new requirements for cutting-edge applications, stakeholders can enhance the interoperability, functionality, and reliability of emerging technologies within established frameworks.

60. Policymakers' eagerness to promote advanced technologies like V2G through mandates or public funding underscores the urgency to address pressing energy challenges and leverage innovative solutions for sustainable grid operation. However, the foundational role of standardized interfaces and protocols in enabling interoperability, scalability, and market integration emphasizes the need to prioritize standardization efforts before widescale deployment to ensure seamless operation and compatibility across diverse systems.

VII. Examples of integration of e-mobility into electricity system

Norway

61. The rapid adoption of EVs in Norway and the successful management of grid integration without significant challenges serve as a significant benchmark for other regions aiming to transition to cleaner transportation systems. In particular, Norway has achieved significant penetration rates of EVs, with over 80 per cent of new cars sold being fully battery electric and a projection that more than 50 per cent of the total car fleet will be electric by the end of 2024. This success underscores Norway's leadership in EV adoption and the effective integration of EVs into the transportation system.

62. Research projects such as "Charging Infrastructure of the Future" and "Mega Charge" are focused on developing cost-effective and user-friendly integration solutions for EV charging infrastructure, particularly high-power charging stations. These projects emphasize the interconnection between the transport system and the power system, highlighting the need to consider the impact of different charging infrastructure types on grid operations and planning.

63. Fast-charging stations are identified as a future flexible resource that can have a substantial impact on the power system. Managing these resources efficiently and considering them as potential assets for grid flexibility are crucial aspects of grid integration planning. Viewing fast-charging stations as more than just a load on the system but also as a valuable resource that can be utilized strategically for grid optimization is key to maximizing their benefits.

64. The "Mega Charge" project focuses on the electrification of heavy-duty transport vehicles, involving various stakeholders along the value chain to address cost-effective deployment of

charging infrastructure, development of charging modules, control system integration, and the utilization of charging services to distribute loads effectively.

65. Successful implementation of the V2G project in Utrecht (Netherlands) has transitioned from the pilot phase into its second year of operation. The positive progress and community-level initiatives are taking place in Utrecht as part of this V2G project. The fact that the project originated from a local necessity to address challenges with the DSO highlights the practical application of V2G technology in solving grid-related issues at a grassroots level. The experience gained from the Utrecht project offers valuable insights and best practices that can be shared with a broader audience to facilitate learning and knowledge exchange. Moving forward, ensuring that information and experiences from successful V2G projects like the one in Utrecht are effectively communicated and disseminated within the wider community can further advance the adoption and implementation of V2G technology in other regions.

United States of America

66. The United States has set ambitious goals for carbon reduction and the transition to EVs, driven by federal and state initiatives focusing on environmental sustainability and the economic viability of the auto industry. The competition from global manufacturers, including those from Europe and China, underscores the urgency to adopt EV technologies and propels innovations in the market.

67. The existing utility grid infrastructure in the U.S. faces challenges in accommodating the rapid adoption of EVs, especially concerning the timing mismatch between the deployment of electric trucks and the grid's capacity to support them. Coordination with the diverse landscape of 3,200 utilities across the U.S. and addressing the complexities of planning and implementing grid upgrades are essential to accelerate EV adoption.

68. Innovative tools, such as eRoadMAP, aim to provide early warning to utilities and prioritize grid upgrades based on anticipated EV loads from cars, buses, and trucks. Leveraging data analytics and telemetry information from major vehicle manufacturers and fleet operators can facilitate informed decision-making and strategic investments in grid infrastructure.

69. Strategies like load shaping, shifting, and shedding are critical to optimizing the charging of EVs and minimizing peak demands on the grid. There is a necessity for scaling up collaboration among automakers, fleet operators, utilities, and regulators to establish reporting standards, transparency, and coordinated efforts towards electrification goals and grid modernization.

70. Transparency in investment plans, available hosting capacity on the grid, and collaborative decision-making processes are vital for aligning stakeholder interests and effectively managing the electrification of fleets. By creating alignment and clarity around deployment priorities and grid upgrades, stakeholders can streamline the transition to EVs and ensure sustainable and cost-effective outcomes.

71. The challenges and opportunities for EV integration within the United States, particularly in the context of fleet electrification. The United States is in the earlier stages of EV adoption compared to countries like Norway, and the robustness of the grid may vary across regions, posing challenges for accommodating high-powered charging loads, especially from fleets. The electrification of trucks and commercial light-duty vehicle fleets, such as those at airports and logistics centers, can introduce significant power demands that may strain local distribution systems and require careful planning to avoid grid congestion.

72. The rapid charging demands of fleet operations, such as car rental agencies at airports, challenge traditional business models that rely on quick turnover and refuelling processes, necessitating innovative solutions for EV charging infrastructure. Collaborating with fleets to explore alternative charging options, including utilizing public charging stations and optimizing charging locations, can help address grid capacity constraints and optimize cost-effective charging solutions. Fleet operators may initially opt for high-power DC fast charging solutions but may later realize the benefits and cost-effectiveness of utilizing level 2 AC charging for their operations.

Educating fleet operators about the grid impact of their charging requirements, the shared costs of grid upgrades, and the importance of right-sizing charging infrastructure can help mitigate grid strains, minimize costs, and ensure sustainable and efficient charging solutions.

Conclusion

73. This document concludes that transition to EVs is crucial for reducing carbon emissions and fossil fuel dependence, with wide-reaching implications for the energy system. While EV integration adds strain to grid infrastructure, smart charging and V2G solutions can optimize energy use and stabilize the grid. Success depends on developing widespread, affordable charging networks, especially in urban and rural areas, and requires strategic planning. In addition, e-mobility demands cross-sector collaboration to align transportation, energy, and infrastructure.

74. At the same time, member States of the United Nations Economic Commission for Europe and beyond have varied levels of experience with e-mobility. Assessment of more examples and best practices can help in sharing different approaches to grid integration, charging infrastructure, and policy frameworks, ensuring that successful practices can be adapted and scaled in other countries. By studying best practices, countries can develop policies that promote e-mobility while ensuring energy security, economic efficiency, and environmental sustainability. Identifying successful examples from different regions is needed to help stakeholders in finding scalable and adaptable practices that can be customized to fit the unique socio-economic and energy contexts.

75. The examples and practices on integrating e-mobility into the energy system can include:

(a) Best practices for developing a supportive policy and regulatory framework to incentivize the adoption of EVs and facilitate their integration with the energy grid;

(b) Examples of innovative charging solutions;

(c) Best practices for leveraging V2G technologies to enable energy flows between EVs and the grid;

(d) Case studies demonstrating the benefits of V2G integration;

(e) Examples of smart grid projects that have successfully integrated e-mobility into grid operations;

(f) Case studies showcasing innovative approaches to combining e-mobility with clean energy generation and storage technologies;

(g) Best practices for utilizing data analytics and energy management systems;

(h) Examples of tools and platforms that enable effective monitoring, control, and optimization of e-mobility operations;

(i) Examples of successful collaborative initiatives and partnerships between stakeholders in the energy and transportation sectors to promote e-mobility integration.