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Smoothing the way: Coaxing more flexible charging from China's mammoth EV fleet

Part of RAP and ICCT's *Benefits of EVs Through Smart Charging* Global Project

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Benefits of EVs through smart charging

This executive summary is part of a global project by the Regulatory Assistance Project (RAP) studying the economic and environmental benefits of deploying smart electric vehicle (EV) charging in specific geographies. The study identifies those benefits as avoided system costs and avoided emissions, and shows how system costs can be reduced based on four use cases in selected areas within the four largest global EV markets: China, the United States, Europe and India.

The global market for EVs is maturing quickly. In China in 2023, about 80,000 zero-emission trucks (ZETs) were sold in the country, a 23% increase in ZET sales from 2022, taking its contribution to 7% of the total truck sales. Similarly, in the EU, the sales of ZETs in 2023 were 3 times the sales in 2022. In the US, the sales of ZETs were 2.3 times the sales in 2022. National and local policies in several jurisdictions targeting tailpipe emissions of road transport vehicles further contributed to this growth, resulting in an increasing global EV fleet over the past decade — these include the European carbon dioxide (CO_2) standards for light-duty vehicles[1] (LDVs) and the light-duty vehicle greenhouse gas emissions regulations in the United States.[2]

With a continuously growing EV fleet, challenges and opportunities arise with regards to its integration into the power grid. If additional demand from EVs remains unmanaged, this would lead to substantial cost increases for meeting their power and delivery needs, as EVs would likely be charged during existing peak periods, thus exacerbating peak demands. If this transition is not managed carefully, the associated growth in electricity demand will lead to higher costs for consumers, the power system and the environment, and may slow down the transition to a cleaner road transport sector.[3,4]

Smart or managed EV charging can help overcome many of these challenges, and EV charging can be utilised to provide optimum system flexibility. Smart charging is a key tool to reduce the consumption of fossil-powered electricity and to integrate more variable renewables into the grid by charging EVs when there is sufficient renewable energy available. In doing so, smart charging can maximise carbon emissions reductions and reduce the need for costly and unnecessary upgrades of the power grid.[5] While smart charging of EV fleets has been studied from the user benefits point of view,[6] it is important to better understand the

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[1] European Commission. (2024, 12 February). *CO_2 emission performance standards for cars and vans*. https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

[2] U.S. Environmental Protection Agency. (2023, 21 November). *Light-Duty vehicle greenhouse gas regulations and standards.* https://www.epa.gov/regulations-emissions-vehicles-and-engines/light-duty-vehicle-greenhouse-gas-regulations-and

[3] Das, H.S., Rahman, M.M., Li, S., & Tan, C.W. (2020, March). Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. *Renewable and Sustainable Energy Reviews,* 120(109618). https://doi.org/10.1016/j.rser.2019.109618

[4] Ashfaq, M., Butt, O., Selvaraj, J., & Rahim, N. (2021, May). Assessment of electric vehicle charging infrastructure and its impact on the electric grid: A review. *International Journal of Green Energy,* 18(7), 657–686. https://doi.org/10.1080/15435075.2021.1875471

[5] Burger, J., Hildermeier, J., Rosenow, J., & Jahn, A. (2022). *The Time is Now. Smart charging of Electric Vehicles in Europe*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/time-is-now-smart-charging-electric-vehicles/

[6] Hildermeier, J., Burger, J., Jahn, A., & Rosenow, J. (2023, January). A Review of Tariffs and Services for Smart Charging of Electric Vehicles in Europe. *Energies,* 16(1), 88. https://www.mdpi.com/1996-1073/16/1/88

value that EVs can have as flexibility assets for the power system[7] and for power networks in large EV markets.[8,9]

This interplay between EVs and power systems represents a significant opportunity for demand flexibility, if policymakers and planners in the power and transport sectors integrate smart charging in decision-making, e.g. charging infrastructure build-out. Results of regional case studies illustrate benefits from smart EV charging for both power sector planning and transport policymakers.

Smoothing the way: Coaxing more flexible charging from China's mammoth EV fleet

China now has the largest electric vehicle (EV) fleet in the world. As EV penetration rates continue to grow, China faces the challenge of updating both its operational procedures and the physical infrastructure of its power grid to support the ongoing electrification of the transportation sector.

While China's top economic planners and power sector reformers recognize the benefits of managed charging and have included elements of needed reform in various regulations, policy documents and long-term plans, detailed implementation still requires further motivation.

To support the ongoing efforts to realize the potential of managed charging, our project team quantified the benefits of smart charging to the grid in Zhejiang Province. Zhejiang, one of the hottest EV hubs in China, is home to almost 2 million EVs,[10] nearly double the number in California, the largest EV state in the United States.[11] Although our study focuses on Zhejiang, the conclusions are broadly generalizable and applicable to other provinces too.

Our analysis addresses the following question: without compromising EV users' transportation needs, what benefits could EV managed charging bring to China's power system? To answer this, our project team looked at a simulation of Zhejiang's transportation and power system in 2040. We estimated the flexibility potential of managed charging by incorporating real and projected EV stock size, usage patterns and characteristics. Then we assessed its impact on least-cost operation and investment decisions.

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[7] International Energy Agency. (2022, December). *Grid Integration of Electric Vehicles - A manual for policy makers*. https://iea.blob.core.windows.net/assets/21fe1dcb-c7ca-4e32-91d4-928715c9d14b/GridIntegrationofElectricVehicles.pdf

[8] Anwar, M.B., Muratori, M., Jadun, P., Hale, E., Bush, B., Denholm, P., Ma, O., & Podkaminer, K. (2022, January). Assessing the value of electric vehicle managed charging: a review of methodologies and results. *Energy & Environmental Science,* 15(2), 466–498. https://doi.org/10.1039/D1EE02206G

[9] Xue, L., Jian, L., Ying, W., Xiaoshi, L., & Ying, X. (2020, January). *Quantifying the Grid Impacts from Large Adoption of Electric Vehicles in China*. World Resources Institute. https://www.wri.org/research/quantifying-grid-impacts-large-adoption-electric-vehicles-china

[10] 浙江省发展改革委员会 [Zhejiang Province Development and Reform Commission]. (2024, August). 浙江省充换电基础设施年度发展报告(2023年度) *[Zhejiang Province 2023 Annual Report on Development of Charging and Battery Swapping Infrastructure]*. https://fzggw.zj.gov.cn/module/download/downfile.jsp?classid=0&filename=47692bd8eda34e848573dfa5bfc981d5.pdf

[11] U.S. Department of Energy. (2024). *Electric Vehicle Registrations by State*. Alternative Fuels Data Center. https://afdc.energy.gov/data/10962

Our findings for Zhejiang Province reveal significant potential benefits from managed charging, for the year 2040:

- **Reduction in coal power capacity:** Managed charging reduces coal power capacity by 17%, helping to decrease reliance on fossil fuels and reduce emissions.
- **Increase in solar photovoltaic (PV) generation:** Managed charging enables 65 GW more solar PV generation without additional costs, improving the integration of renewable energy into the grid.
- **Cost savings:** Managed charging saves Zhejiang Province RMB 2 billion (approximately USD 280 million) through reduced coal-fired power plant investment and higher renewable energy integration.

In addition, from the perspective of grid dispatchers or system operators, managed charging can contribute to smoother grid operations. Our findings show that on the most demand-heavy day, managed charging can reduce peak demand by 7% and decrease ramping rates by nearly 50%.

Detailed information on the modelling results and methods of this project may be found on our website, in Chinese and in English.

The analysis demonstrates that managed charging can reduce peak capacity, complement variable renewable energy resources, and generate substantial cost savings for the entire power system. This flexibility potential could be a valuable solution to China's current challenge of phasing out coal-fired power plants and integrating renewable energy, while controlling costs. Importantly, achieving this vision requires policymakers, power sector planners and operators to recognize and integrate this capability into planning and operational practices.

Fortunately, a new policy window of opportunity opened in late 2023 when the National Development and Reform Commission (NDRC) published the *Implementation Opinion on Enhancing Integration between New Energy Vehicles and the Grid*.[12] This regulation sets explicit goals for managed charging, including standard setting, expanding smart rate designs for EV charging, and enlarging the flexibility potential of EV fleets. The new policy document also calls for the refinement of existing rate design and policy tools, such as time-of-use (TOU) rates and market instruments.

To provide concrete ideas for fleshing out NDRC's statement and to aid in effective implementation, RAP published policy briefs (in Chinese) providing suggestions for improving policy to expedite the rollout of managed charging in three areas:

- Integrated EV and power sector co-planning.
- TOU rate design.
- Leverage automatic charging control to unlock residential flexibility.

[12] NDRC. (2023). 关于加强新能源汽车与电网融合互动的实施意见 *[Implementation Opinions on Strengthening the Integration and Interaction between New Energy Vehicles and the Power Grid]*. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202401/t20240104_1363096.html

The first brief emphasizes that the first step to realizing the potential of managed charging is to include it in power sector investment and buildout plans.[13] Grid planners need to adopt integrated co-planning practices with transportation agencies and a wide range of EV-related stakeholders to precisely estimate both the capabilities and limitations of EV managed charging. This is a critical step, as planning around flexible load, including managed charging, is still a relatively nascent practice. Establishing a clear policy framework governing co-planning practices is the prerequisite for grid planners to embrace this untapped resource.

The second brief points out that while policymakers have made great strides toward implementing TOU rates widely, including for some segments of EV charging, current TOU designs require refinement to unlock the full value of managed charging.[14] More specifically, compensation for the value of managed charging could be refined along two aspects: time and space. Timewise, current TOU rates prioritize optimization over short-term system operations but often overlook the long-term investment perspective – that is, avoiding or delaying network and generation capacity expansion. Regarding the space dimension, current TOU rates are designed at the provincial level, leaving significant value unexplored for local grids. More localized TOU rate designs are needed to address specific local grid stresses.

The third brief discusses leveraging maturing automatic charging control technologies to unlock residential EV charging flexibility. Due to political and institutional factors, residential flexibility resources are traditionally deemed undesirable and unreliable. However, automatic charging control technologies offer a solution that promises to make residential flexibility resources both politically palatable and technologically reliable. Additionally, the brief suggests combining monthly rebates with automatic control as a feasible business model. This business model separates grid services from market-based compensation, allowing local utilities to experiment with and realize the latent benefits of charging flexibility. These programmes can generate local benefits now while preparing for future market integration.

Co-planning, refined TOU rate design, and automatic charging control in residential sector are three areas this study identifies to best realize the benefits of EV managed charging, as highlighted by our model. These focus areas leverage the current policy window of opportunity by expanding on existing EV managed charging policies and initiatives in China and incorporate international best practices to expedite the progress of EV managed charging.

[13] Gao, C. (2024, November). 交通+电力协同规划：解锁车网融合灵活性效益 [*Co-planning of Transportation and Power Sectors: Unlocking the Flexibility Benefits of Vehicle-Grid Integration].* Published on 南方能源观察 [Southern Grid Observer Magazine]. https://mp.weixin.qq.com/s/2t2IVAqp4yUL6f5-K-ei-A

[14] Gao, C.. (2024 December). 完善分时电价设计，促进车网互动 *[Refine Time-of-Use Electricity Pricing Design to Promote Vehicle-Grid Interaction].* Published on 南方能源观察 [Southern Grid Observer Magazine]. https://mp.weixin.qq.com/s/yEjzYWn1kIJ0T-25zki_qg

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