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# How to unlock benefits from smart EV charging: Key lessons from a global study

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

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## Contents



## How to unlock benefits from smart EV charging: Key lessons from a global study

Optimized or 'smart' charging of electric vehicles (EVs) can save money on power grids and generate multiple benefits for users, the power system and the environment. This guide summarizes the findings and conclusions from four global case studies that the Regulatory Assistance Project (RAP) conducted in collaboration with the International Council for Clean Transportation (ICCT) and local grid modelers to estimate the economic and environmental benefits of smart EV charging in the United States, Europe, India and China.

In all four regions, our analysis shows that monetary savings can be generated by unlocking EVs' flexibility potential via smart charging. Savings come from two sources:

- EVs' flexibility can be used to flatten system peaks, which avoids investment in transmission and distribution infrastructure, and more effectively uses existing grid capacity.
- EVs' flexibility can help avoid investments in generation capacity and related battery storage.

By displacing other expensive, emission-intensive generation sources, smart EV charging also helps to decrease reliance on fossil generation (e.g., coal powered capacity) and improves the integration of renewable energy into the grid.

To unlock these savings while planning for the electrification of vehicle fleets, policymakers and planners should consider the following high-level recommendations.

**Recommendation 1: Coordinate planning** for transport electrification (e.g., anticipate charging demand of fleets and related charging infrastructure build-out) with power network planning, to save costs.

**Recommendation 2: Pricing of energy and power networks should be cost-reflective** so users (e.g., EV fleets) receive accurate signals for when to optimize their charging and save system costs.

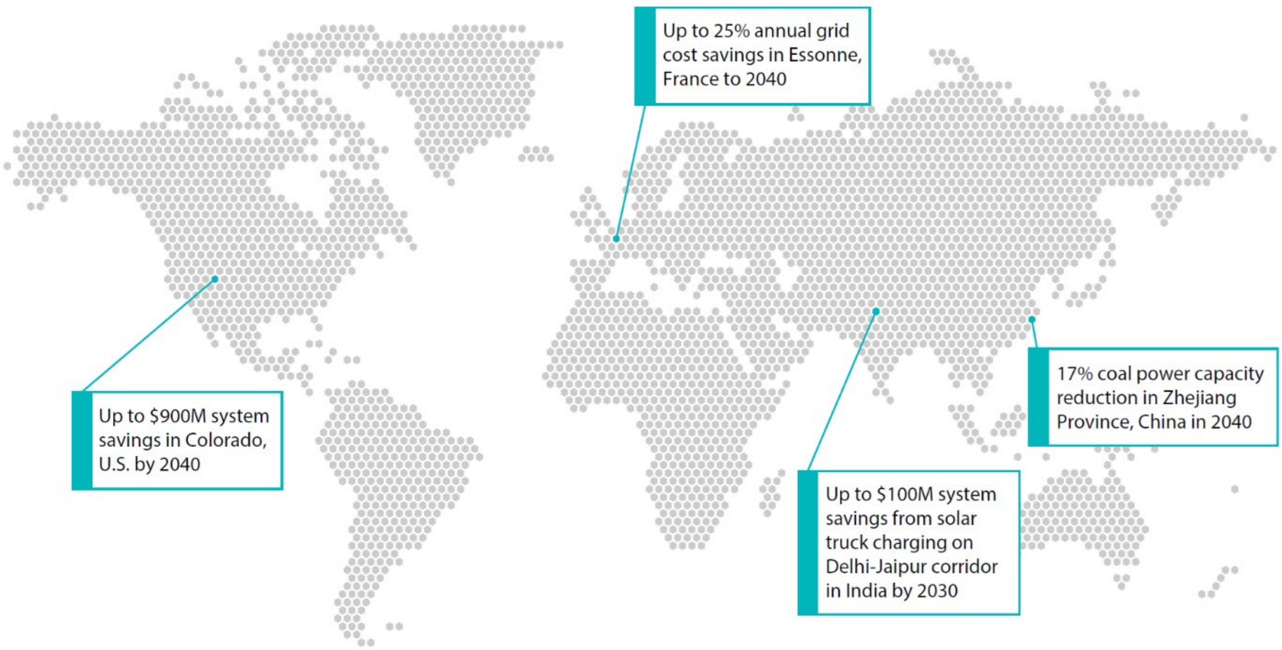
# Smart EV charging: Barriers and policy solutions

EV markets are maturing in China, growing in Europe and the United States, and starting to grow in India. That is good news. But as electric car and truck numbers rise across the globe, the challenge is not only to accelerate their sales, but also to ensure their smooth and effective integration into the power grid. If not managed carefully, the growth in electricity demand will lead to higher costs for consumers, the power system and the environment, and may eventually slow down the clean energy transition.

The solution to this challenge is managed or "smart" EV charging, which reduces consumption of fossil-powered electricity and helps absorb more clean energy onto the grid by charging EVs when renewable sources are available. Smart charging also benefits consumers by reducing charging costs. It also limits overall electricity costs through system savings, thus further improving the case for electrification of the EV fleet. Smart charging is the essential ingredient for a successful EV transition and should be part of planning for transportation electrification from the outset.

RAP and the ICCT partnered to analyze the grid benefits from smart EV charging in selected regions across the four largest EV markets: China, Europe, the United States and India. We defined smart charging as avoiding grid costs by charging EVs when electricity prices are lowest. To study benefits in terms of avoided grid costs, we modelled charging demand from expected EVs, the impact of optimizing this charging on regional power networks, as well as broader power market effects such as displaced fossil generation. This guide summarizes key insights from the four case studies and provides further policy recommendations for each region. Figure 1 quantifies some of the benefits.

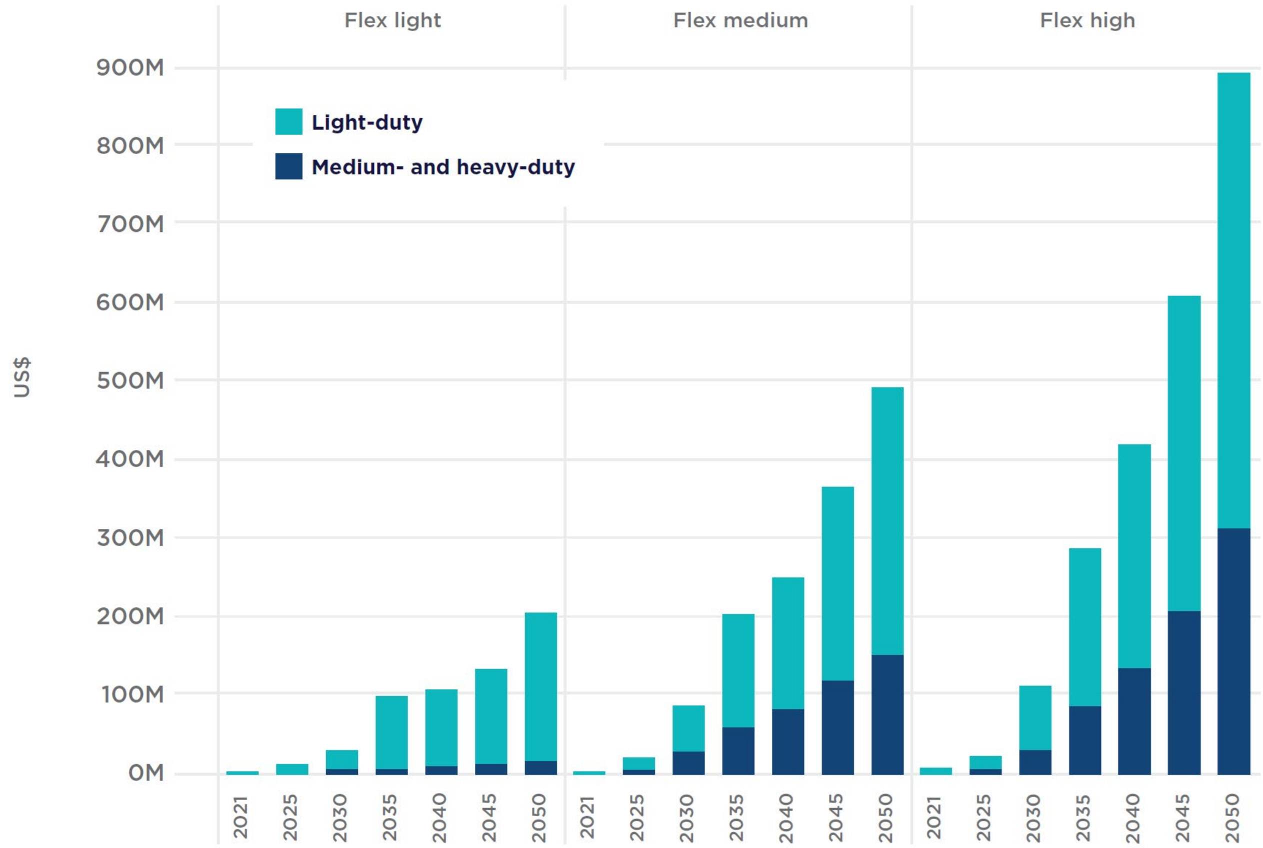
**Figure 1. Key findings from the 'Benefits of EVs Through Smart Charging' global project**



# United States: Leverage residential EV charging savings to accelerate the energy transition

Our analysis of the value of EV flexibility in the U.S. state of Colorado revealed the potential for significant savings. Between US$300 million and US$900 million can be saved by optimizing the charging of electric light-duty vehicles (i.e., passenger cars) and medium- and heavy-duty vehicles (i.e., trucks and buses) (Figure 2).[1] The savings result from the reduced need for investment in generation, transmission and distribution infrastructure. Increased flexibility, furthermore, leads to more savings throughout the forecast period, 2025-2040. The largest share of savings comes from residential charging, which represents about two-thirds of overall potential savings. The savings are so large that they could pay for all the charging infrastructure (Level 2, AC charging) that is required in the sector.

**Figure 2. Electricity system savings from smart EV charging in Colorado, United States**




Source: Evolved Energy Research. (2024, May). *Analyzing the Value of Vehicle Flexibility to Colorado's Energy System*

[1] Evolved Energy Research. (2024, May). *Analyzing the value of vehicle flexibility to Colorado's energy system*. https://www.evolved.energy/post/value-of-flexible-ev-load-in-co

### Policy recommendations

To realize the potential of EV flexibility to reduce cost, state utility commissions can encourage utilities to:

- Design incentive programs (e.g., rebates and tariffs) for the residential sector first, then focus on capturing flexibility in other sectors.
- Bundle incentive programs with complementary tariffs that increase the benefits of the incentive program(s).
- Ensure that incentive programs are well integrated into utility operating systems, to enable utilities to monitor, measure and control the EV loads that are enrolled in their programs.
- Ensure that incentive programs are well integrated into utility planning processes. This helps to ensure that the investments in the program are offset by reduced investment in generation, transmission and distribution infrastructure.

Full study: Farnsworth, D., Enterline S., Basma, H., Kadoch, C. (2024). Unlocking System Savings with Flexible EV Charging: Lessons from Colorado.

Further reading: Farnsworth, D., Kadoch, C., Enterline, S., Wang, X., and Valainis, A. (2024). It's 10 p.m. Do You Know Where Your Electric Vehicles Are?

# Europe: Reduce peak load and grid cost with smart EV charging at workplaces, homes and depots

For Europe, we studied the grid benefits of smart EV charging in the French region of Essonne, south of Paris, which comprises a well-developed, urban and rural power network representative of many other European regions. We analyzed savings from an optimally charging fleet of electric passenger and heavy-duty vehicles forecasted for the region in 2040.[2] Our key insights were:

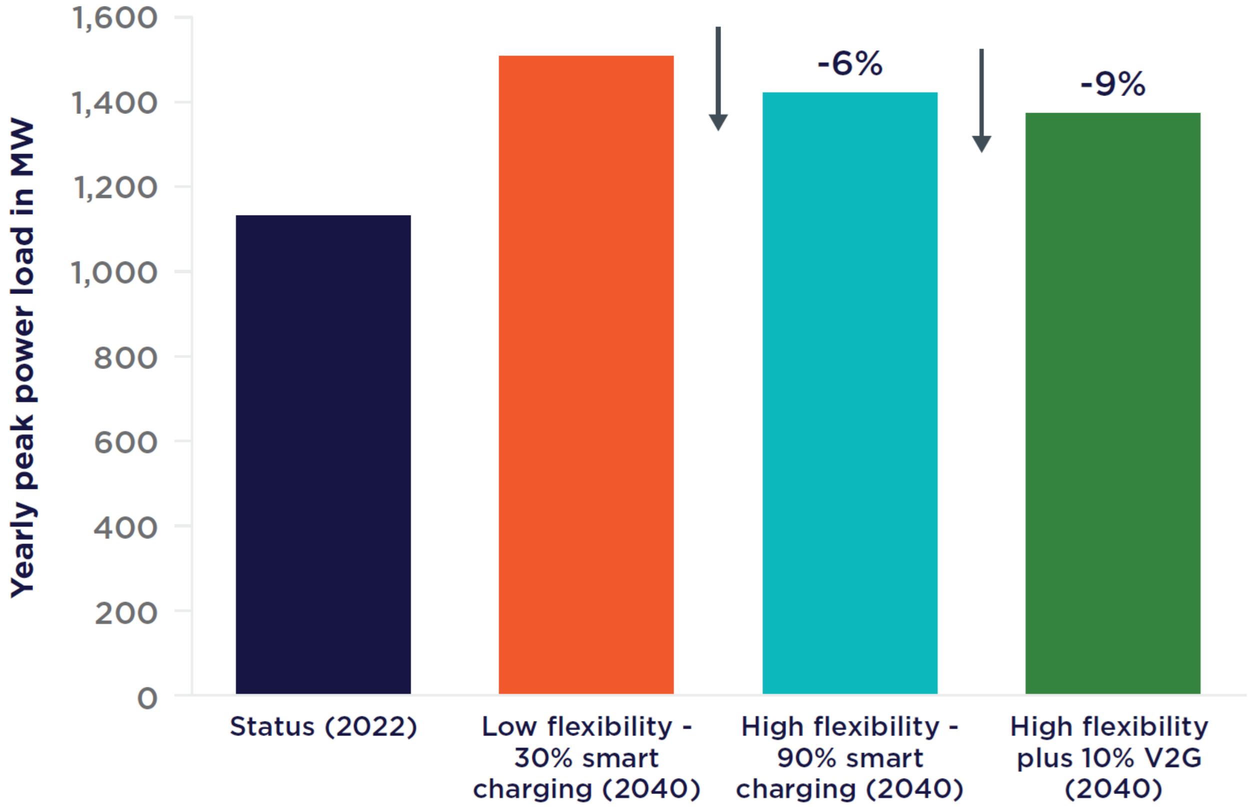
- Smart charging of the EV fleet can reduce peak load on electricity grids and related system costs. In our case study, smart charging can **reduce peak load on the grid by 6% in 2040**, compared to uncontrolled charging.
- **Bi-directional charging** – that is, discharging energy from EVs back into the grid at peak demand times – can add an **even greater reduction** of 9% in 2040, compared to uncontrolled charging (see Figure 3).[3]

[2] Artelys. (2025, March 12). *Savings from smart charging electric cars and trucks in Europe: A case study for France in 2040. Technical report.* https://www.artelys.com/app/uploads/2025/03/Savings_from_smart_charging_Technical_Report_Artelys.pdf

[3] International Council on Clean Transportation. (2025, March 18). *Smart charging for Europe: How EVs can save money for power grids* [Webinar]. https://www.youtube.com/watch?v=Kpdput5jlzU

- Smart charging **works for all use cases**, including smart residential overnight charging, optimized daytime charging of EV fleets at workplaces, and optimized charging of electric trucks at freight depots.
- **Smart charging also avoids distribution system costs** by flattening system peaks. In our analysis, smart charging in 2040 could reduce the need for power line reinforcements by 23%, with 37% less transformer reinforcements in Essonne. A broad estimate suggests that **smart EV charging avoids about one-quarter of yearly network reinforcement costs** in the area.

**Figure 3. Peak load savings from smart EV charging for Essonne, France**




Source: International Council on Clean Transportation. (2025, March 18). *Smart Charging for Europe: How EVs Can Save Money for Power Grids*

## Policy recommendations

To make EV grid integration cost-efficient and to enhance rapid transport electrification in Europe, policymakers and national energy regulators can:

- Ensure that smart residential and workplace charging for EVs and smart depot charging for e-trucks are the default modes of charging as they offer the largest grid savings potential.
- Broadly introduce cost-reflective pricing of power networks (e.g., through time-varying network pricing) to incentivize smart EV charging.

- Require transparency on network use from distribution grid operators to design and implement more cost-reflective tariffs.
- Allow EVs to participate as flexibility resources in energy markets, thereby generating value for customers through demand-response programs (e.g., via smart tariffs and services).
- Ensure coherent, balanced and grid-beneficial charging infrastructure planning, including granular and systematic forecasting of demand from e-transportation.

Full study: Hildermeier, J., Jahn, A., Schmidt, J., Rajon Bernard, M., Ragon, P., and Basma, H. (2025). Savings from smart charging electric cars and trucks in Europe: A case study for France in 2040.

## India: Help electrify freight corridors with smart solar charging

India's EV market is projected to grow strongly, with significant potential to reduce emissions, especially in the heavy-duty sector. Electrification of freight is recognized as a key strategy area by the Indian government, which has identified 12 corridors for freight electrification. We analyzed benefits of smart truck charging on one strategic corridor, Delhi to Jaipur, based on a hypothetical shifting of charging patterns to absorb cheap, abundant solar energy (smart solar charging) assuming sufficient grid capacity.

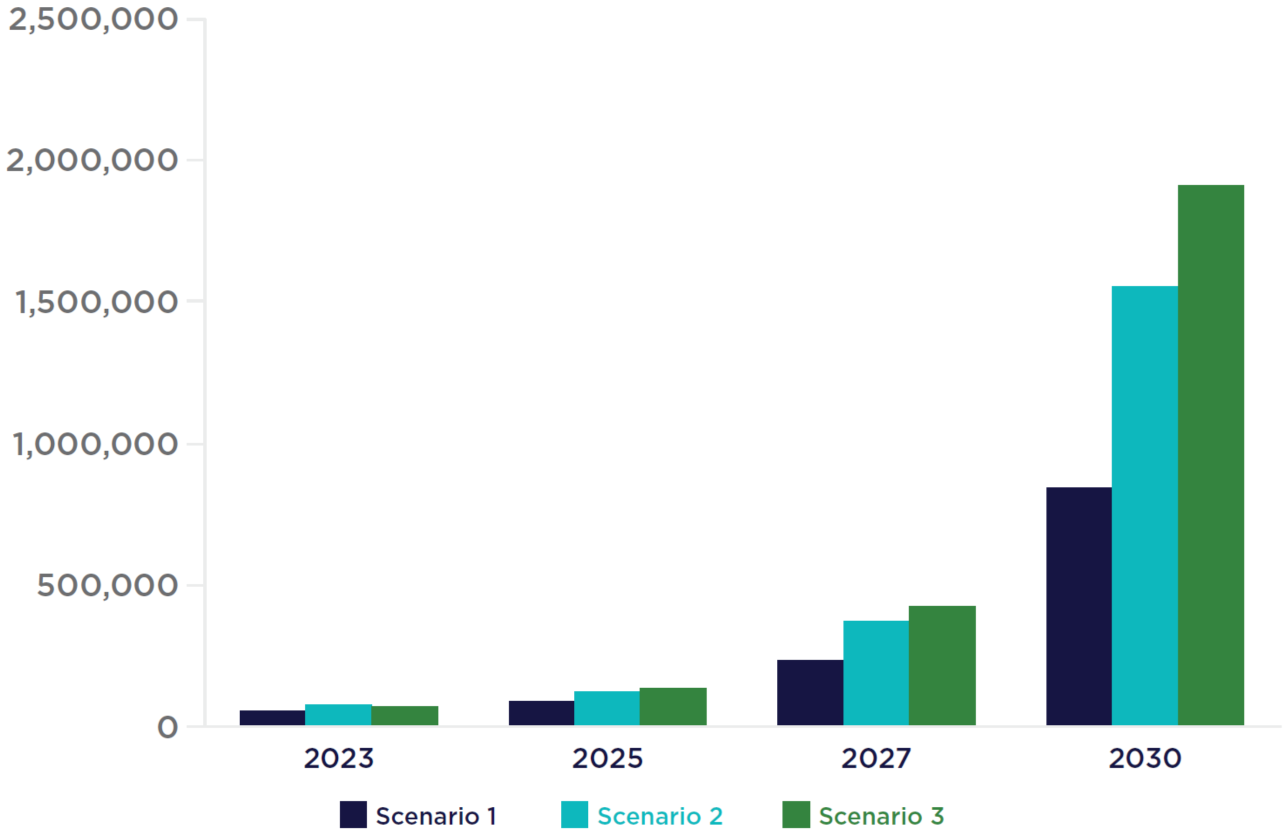
Key findings of our scenario analysis[4] were:

- The daily value of smart solar charging of e-trucks on the Jaipur-Delhi corridor could be from INR 0.8 million to INR 1.9 million by 2030, depending on the level of flexibility unlocked (Figure 4[5]).
- This amounts to annual savings from smart charging in the electricity system of INR 300 million to INR 700 million (US$3.6 million to US$8.4 million at time of analysis) by 2030.
- If, as envisaged by the Indian government, India accommodates a dozen such corridors, annual savings could be in the range of INR 3.5 billion to INR 8.5 billion (US$45 million to US$100 million at time of analysis).
- Greenhouse gas reductions from increased solar power across a dozen such corridors could help reduce carbon emissions by as much as 1 million to 3.5 million metric tons.

[4] MP Ensystems Advisory Pvt. Ltd. (2024). *Smart charging in India.* https://www.mpensystems.com/smart-charging-in-india-study-on-ev-freight-corridor-and-grid-final-versionpdf

[5] MP Ensystems Advisory Pvt. Ltd., 2024.

**Figure 4. Societal benefits from solar smart charging (proxied by change in total profit of utility), in INR/day**




Source: MP Ensystems Advisory Pvt. Ltd. (2024). *Smart Charging in India*

Note: Scenario 1 shifts EV demand above daily average from non-solar hours to solar hours, and Scenario 3 shifts all non-solar hour demand to solar hours, with Scenario 2 in between.

## Policy recommendations

To secure these benefits as trucks electrify, policymakers can:

- Strategically plan and deliver the enabling infrastructure to unlock flexibility offered by smart charging
- Codify in regulation the objective of integrating EVs (including trucks) at lowest cost, through EV-based demand response and smart charging.
- Introduce tariff designs that reflect cost in a granular and marginal way – both in time and location – and that encompass all costs, including wholesale, network and relevant environmental costs such as carbon. In the short term, solar rebates – which provide more efficient signals over the day (but not by location), and which are being introduced – can enable smart charging where grid capacity is abundant.

Full study: Hildermeier, J., Scott, D., Reddy, S., Kaur, H., and Thakur, P. (2024). Optimising electric heavy-duty truck charging in India.

# China: Reducing reliance on coal power by fully leveraging EV flexibility

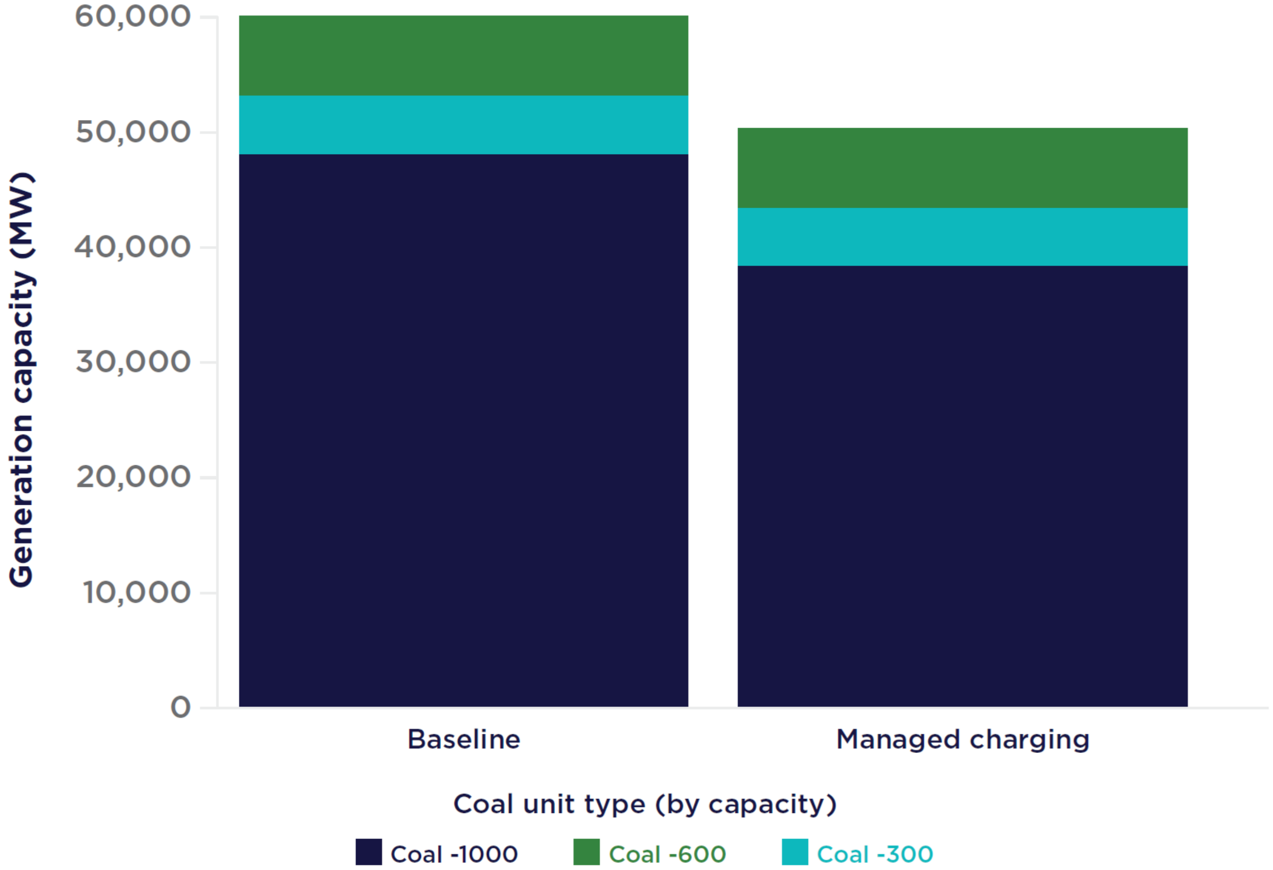
China now has the largest EV fleet in the world. Though the country's economic planners and power sector reformers recognize the benefits of smart charging in various regulations, China still faces the challenge of updating both the operational procedures and the physical infrastructure of its power grid to support the ongoing electrification of the transport sector. The key to achieve this is to harness the full potential of smart charging to reduce peak demand, complement variable renewable energy resources, and generate substantial cost savings for the entire power system while reducing reliance on fossil energy generation.

To support policymakers' and planners' ongoing efforts, we modeled benefits of managed charging on the grid in Zhejiang Province, home to almost 2 million EVs – nearly twice as many as California. Our findings revealed significant benefits:

- **Reduction in coal power capacity:** Managed charging reduces required coal power capacity by 17%, helping to decrease reliance on fossil fuels and reduce emissions (see Figure 5).[6]
- **Increase in solar photovoltaic generation:** Managed charging enables 65 GW more solar PV generation without increasing overall system costs, improving the integration of renewable energy into the grid.
- **Cost savings:** Managed charging saves Zhejiang Province RMB 2 billion (US$280 million at time of analysis) annually through reduced coal-fired power plant investment and higher renewable energy integration.

[6] Gao, C. (2025, March). "Quantifying benefits of EV smart charging" project model in China [Presentation]. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/quantifying-benefits-of-ev-smart-charging-project-model-in-china/

**Figure 5. Projected coal generation capacity scenarios in Zhejiang Province in 2040**




Source: Gao, C. (2025, March). "*Quantifying Benefits of EV Smart Charging" Project Model in China*

## Policy recommendations

To fully realize the power system benefits of smart EV charging, policymakers and planners can:

- Integrate energy and transport planning. To include EVs' flexibility potential in power sector investment and buildout plans, grid planners can estimate EV demand and adopt joint planning practices with transportation agencies and EV ecosystem stakeholders to estimate both the capabilities and limitations of EV managed charging.
- Refine time-of-use (TOU) rate design. While TOU rates are already available for some segments of EV charging (e.g., for charging in public), current TOU designs could be refined to unlock the full value of managed charging. This could include designing TOU rates in ways that avoid or delay the expansion of network and generation capacity, as well as introducing more localized TOU rate designs to address local grid constraints.
- Leverage automatic charging control technologies to fully unlock residential EV charging flexibility in a technologically reliable and politically feasible way.

Full study: Gao, C. (2025). Smoothing the way: Coaxing more flexible charging from China's mammoth EV fleet.

Further reading:
Gao, C. (2024). Improve the design of time-of-use electricity prices and promote vehicle-grid interaction [in Chinese].

Gao, C. (2024). Transport and Energy Sector Co-planning: Unlock the Flexibility Benefits of Vehicle-Grid Integration [in Chinese].

Gao, C., and Wang, X. (2025). Unlocking Residential EV Charging Flexibility Through Automatic Charging Control [in Chinese].

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