

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

|                                     |  |
|-------------------------------------|--|
| n/a                                 | Confirmed  |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> The exact sample size ( <i>n</i> ) for each experimental group/condition, given as a discrete number and unit of measurement   |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> The statistical test(s) used AND whether they are one- or two-sided<br><i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A description of all covariates tested  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons   |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For null hypothesis testing, the test statistic (e.g. <i>F</i> , <i>t</i> , <i>r</i> ) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted<br><i>Give P values as exact values whenever suitable.</i>                                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Estimates of effect sizes (e.g. Cohen's <i>d</i> , Pearson's <i>r</i> ), indicating how they were calculated  |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

|                 |   |
|-----------------|---|
| Data collection | None of commercial, open source or custom code is used to collect the data in this study.   |
| Data analysis   | <p>A Commercial code is used:</p> <p>1. Gurobi (12.0.0) for V2G optimization. We have an academic license of Gurobi.</p> <p>Several open-source tools are used:</p> <p>1. Python (Version 3.9.21) and packages (1) Numpy (Version 1.26.4) for numerical computation, (2) joblib (Version 1.4.2) for parallel computation, (3) pandas (Version 2.2.3) for data collation and data visualization, (4) scikit-learn (Version 1.5.2) for generating random variables, (5) matplotlib (Version 3.9.2) for data presentation, (6) seaborn (Version 0.13.2) for data presentation.</p> <p>Custom codes are developed based on Python and Gurobi. They include</p> <p>1. Mobility model-related codes, for extracting individual travelling parameters, and accordingly simulate user travelling trajectories.</p> <p>2. Charging behavior-related codes, for simulating charging decisions of P-PEVs, and calculating energy consumption during moving.</p> <p>3. V2G optimization codes, for conducting linear-programming based on Gurobi.</p> <p>4. Evaluation codes, for calculating V2G-related metrics (weekly discharged energy, compensation costs, battery degradation costs, user satisfaction).</p> <p>All necessary codes for reproduction are provided in CodeOcean repository.</p> |

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

## Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The data generated in this study have been partially deposited at the CodeOcean repository (<https://doi.org/10.24433/CO.2863234.v1>). Full data are available under restricted access for related confidentiality agreements, access can be obtained by contacting the corresponding author. Source data for reproducing the figures are available at Figshare repository (<https://doi.org/10.6084/m9.figshare.27950028>). Source data are provided as a Source Data file. Source data are provided with this paper.

## Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender

This study is about energy management and does not involve human participants or biological variables. Therefore

1. The terms "sex" and "gender" are not applicable to the research focus.
2. Sex and gender are not considered in the study design.
3. No sex or gender data are collected.
4. Sex- and gender-based analyses are not performed.

Reporting on race, ethnicity, or other socially relevant groupings

This study is about energy management and does not involve human participants or socially constructed categories. Therefore

1. The terms "race", "ethnicity", or other socially relevant groupings are not applicable to the research focus.
2. No socially constructed categories were considered in the study design.
3. No data on race, ethnicity, or other socially relevant groupings were collected.

Population characteristics

See above.

Recruitment

No participants were recruited in this study.

Ethics oversight

As explained above, no protocol is related.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

## Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

The study is a quantitative simulative work.

Research sample

No specific research samples are used and no relevant demographic information is introduced in the study. Datasets are collected from Shenzhen Municipal Development and Reform Commission, Shenzhen Municipal Transport Bureau, and a published book. Datasets are anonymized. They are either illustrated in the manuscript or available on request.

Sampling strategy

No sampling strategy is used in the study.

Data collection

No data collection techniques are used. Datasets are directly provided by Shenzhen Municipal Development and Reform Commission, Shenzhen Municipal Transport Bureau, and a published book.

Timing

Shenzhen P-PEV Trajectories Dataset and Beijing P-PEV Trajectories Dataset start in October 1, 2022 and stop in December 31, 2022. Charging information provided by the published book start in January 1, 2019 and stop in December 31, 2019.

Data exclusions

No data were excluded from the analysis.

Non-participation

No Non-participation information is involved.

Randomization

No randomization is involved.

## Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

### Materials & experimental systems

- |                                     |  |
|-------------------------------------|--|
| n/a                                 | Involved in the study                                  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Antibodies                    |
| <input type="checkbox"/>            | <input type="checkbox"/> Eukaryotic cell lines         |
| <input type="checkbox"/>            | <input type="checkbox"/> Palaeontology and archaeology |
| <input type="checkbox"/>            | <input type="checkbox"/> Animals and other organisms   |
| <input type="checkbox"/>            | <input type="checkbox"/> Clinical data                 |
| <input type="checkbox"/>            | <input type="checkbox"/> Dual use research of concern  |
| <input type="checkbox"/>            | <input type="checkbox"/> Plants                        |

### Methods

- |                                     |   |
|-------------------------------------|---|
| n/a                                 | Involved in the study                           |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> ChIP-seq               |
| <input type="checkbox"/>            | <input type="checkbox"/> Flow cytometry         |
| <input type="checkbox"/>            | <input type="checkbox"/> MRI-based neuroimaging |

## Eukaryotic cell lines

Policy information about [cell lines and Sex and Gender in Research](#)

Cell line source(s)

No cell line source is used in the study.

Authentication

No authentication is involved.

Mycoplasma contamination

No mycoplasma contamination is involved.

Commonly misidentified lines  
(See [ICLAC](#) register)

No misidentified cell lines are involved.

## Palaeontology and Archaeology

Specimen provenance

The study is not about palaeontology and archaeology. No specimen is involved.

Specimen deposition

See above.

Dating methods

See above.

☐ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.

Ethics oversight

See above.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Animals and other research organisms

Policy information about [studies involving animals; ARRIVE guidelines](#) recommended for reporting animal research, and [Sex and Gender in Research](#)

Laboratory animals

The study is not about animals. No animals are involved.

Wild animals

See above.

Reporting on sex

See above.

Field-collected samples

See above.

Ethics oversight

See above.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Clinical data

Policy information about [clinical studies](#)

All manuscripts should comply with the ICMJE [guidelines for publication of clinical research](#) and a completed [CONSORT checklist](#) must be included with all submissions.

|                             |  |
|-----------------------------|--|
| Clinical trial registration | The study is not a clinical work. No clinical trial is involved. |
| Study protocol              | See above.   |
| Data collection             | See above.   |
| Outcomes                    | See above.   |

## Dual use research of concern

Policy information about [dual use research of concern](#)

### Hazards

Could the accidental, deliberate or reckless misuse of agents or technologies generated in the work, or the application of information presented in the manuscript, pose a threat to:

| No                                  | Yes   |
|-------------------------------------|---|
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Public health              |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> National security          |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Crops and/or livestock     |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Ecosystems                 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Any other significant area |

### Experiments of concern

Does the work involve any of these experiments of concern:

| No                                  | Yes  |
|-------------------------------------|--|
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Demonstrate how to render a vaccine ineffective                             |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Confer resistance to therapeutically useful antibiotics or antiviral agents |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Enhance the virulence of a pathogen or render a nonpathogen virulent        |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Increase transmissibility of a pathogen                                     |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Alter the host range of a pathogen  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Enable evasion of diagnostic/detection modalities                           |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Enable the weaponization of a biological agent or toxin                     |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Any other potentially harmful combination of experiments and agents         |

## Plants

|                       |  |
|-----------------------|--|
| Seed stocks           | The study is not about plants. No seed stocks are involved in the study. |
| Novel plant genotypes | See above.   |
| Authentication        | See above.   |

## Flow Cytometry

### Plots

Confirm that:

- ☐ The axis labels state the marker and fluorochrome used (e.g. CD4-FITC).
- ☐ The axis scales are clearly visible. Include numbers along axes only for bottom left plot of group (a 'group' is an analysis of identical markers).
- ☐ All plots are contour plots with outliers or pseudocolor plots.
- ☐ A numerical value for number of cells or percentage (with statistics) is provided.

### Methodology

- Sample preparation
- Instrument
- Software
- Cell population abundance
- Gating strategy
- ☐ Tick this box to confirm that a figure exemplifying the gating strategy is provided in the Supplementary Information.

## Magnetic resonance imaging

### Experimental design

- Design type
- Design specifications
- Behavioral performance measures

### Acquisition

- Imaging type(s)
- Field strength
- Sequence & imaging parameters
- Area of acquisition
- Diffusion MRI ☐ Used ☒ Not used

### Preprocessing

- Preprocessing software
- Normalization
- Normalization template
- Noise and artifact removal
- Volume censoring

### Statistical modeling & inference

- Model type and settings
- Effect(s) tested
- Specify type of analysis: ☐ Whole brain ☐ ROI-based ☐ Both

Statistic type for inference

See above.

(See [Eklund et al. 2016](#))

Correction

See above.

Models & analysis

|                                     |   |
|-------------------------------------|---|
| n/a                                 | Involved in the study   |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Functional and/or effective connectivity     |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Graph analysis                               |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Multivariate modeling or predictive analysis |