A Model to Evaluate Coupled Driving-and-Charging Incentives for Electric Vehicles

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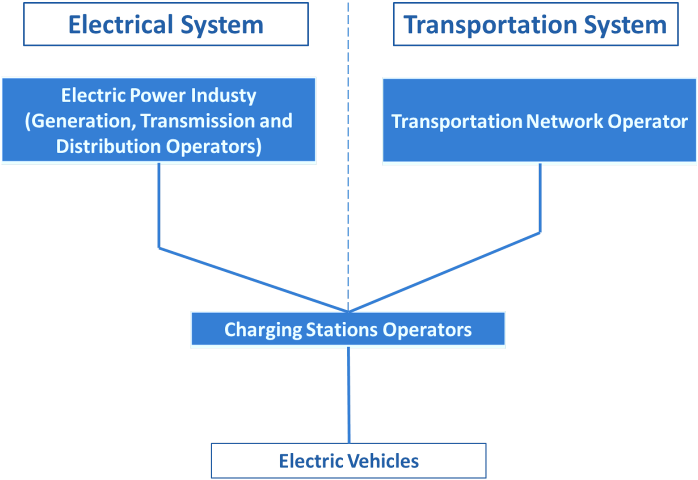
Context: Coupled electrical and transportation systems



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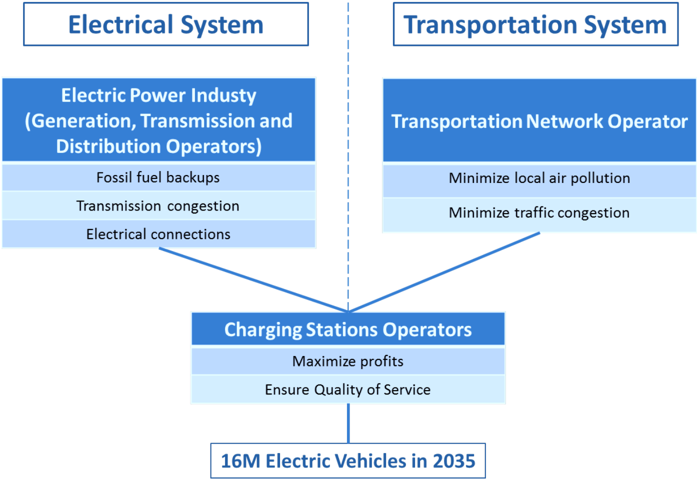

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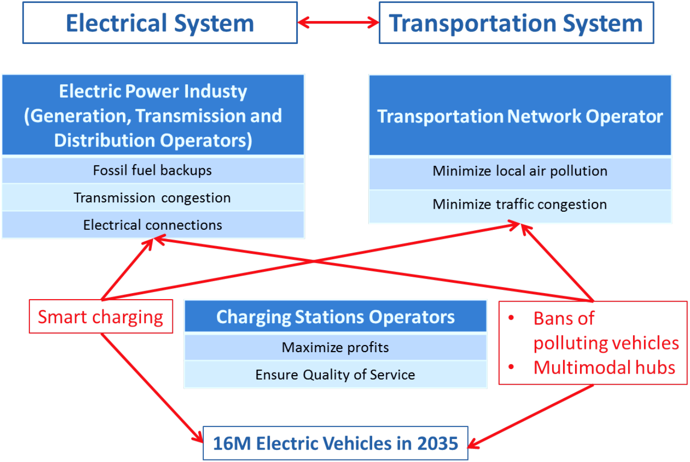
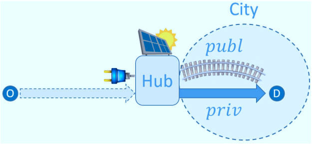


Scenario: e-Park & Ride hub

A group of **E**lectric and **G**asoline **V**ehicles (EV and GV) arrives at an e-Park & Ride hub. They can either:

1. Park and charge at the hub with its **P**hoto**V**oltaic (PV) solar panels, and take **P**ublic **T**ransport (PT);
2. Drive all the way to the city center.



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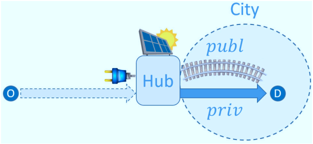
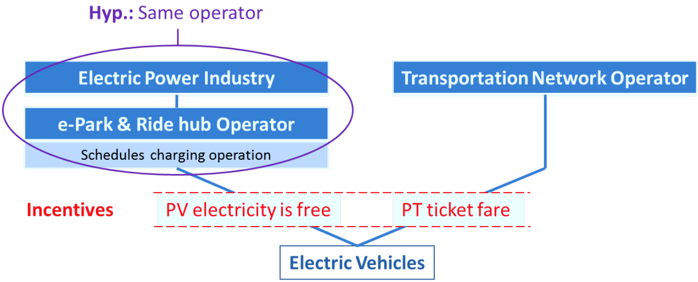
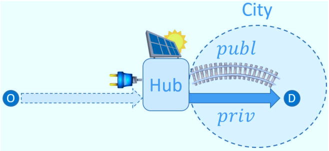




Model: Minimize duration and price

publl Pay for energy consumed to get to the hub and take Public Transport

priv Drive into congested city center and pay for total energy consumed



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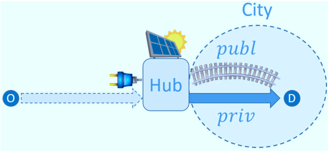

Transport mode	Travel duration	Consumption cost
Public	• Constant	• Charging price depends on EV nb + Constant PT fare
Private	• Depends on vehicles nb (congestion) → BPR function	• Constant (distance-dependent)

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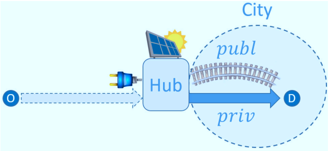

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Equilibrium

Stable situation between strategic decision-makers

Hub charging service

At the hub, the operator schedules the charging operation to minimize the costs related to peak demand.

- **Constraint:** Total charging need L_e ($\propto$ EV nb at the hub)
- **Control:** Aggregated charging profile $(\ell_{e,t})_t$
  s.t. $\sum_{t=1}^{T} \ell_{e,t} = L_e$

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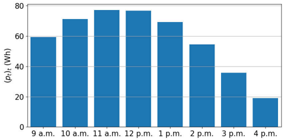

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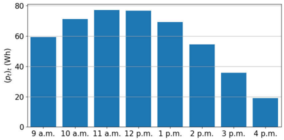

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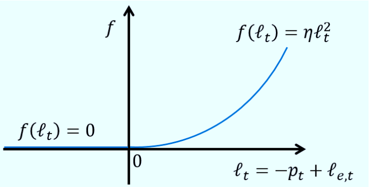

- **Objective:** Minimize electricity distribution costs f

Charging unit price

- Optimal aggregated charging profile $\longrightarrow$ Minimal distribution costs val
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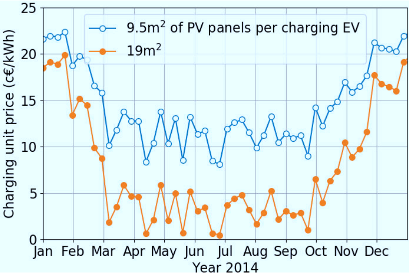


- PV panels located in Paris[a]
- Hub charging service cheaper from March to October
- Depending on nb of EV at the hub, charging may be free or not (see end of June)

[a] `https://www.renewables.ninja/`

Sensitivity analysis: Public Transport fare

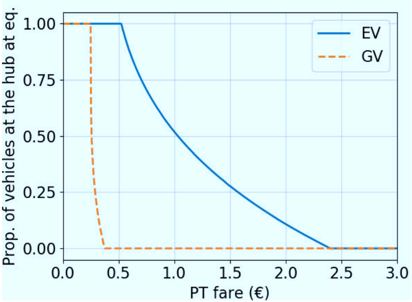


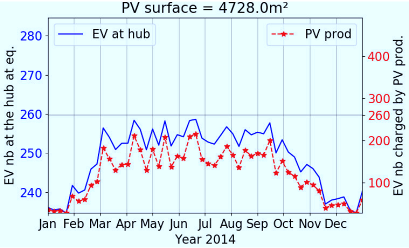
Figure: Equilibrium computed for any PT fare

- More EV than GV at the hub thanks to charging incentives (PhotoVoltaic production provided for free)
- $\searrow$ 0.50€ Public Transport fare $\longrightarrow$ +25% of EV at the hub

Sensitivity analysis: PhotoVoltaic surface

Parameters

- Total number of EV = 500
- PT fare = 1€
  $\longrightarrow$ no GV at the hub at eq.



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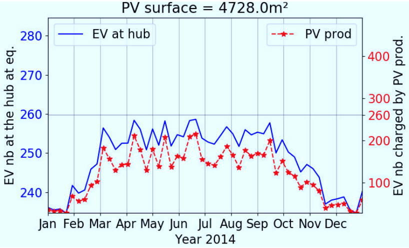
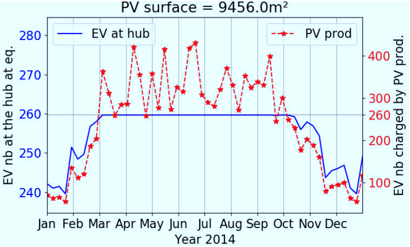
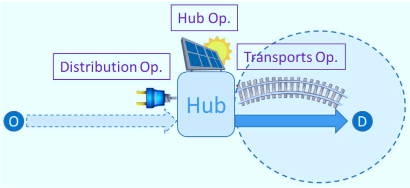


- EV may charge at the hub even if it is not free
- EV may charge downtown even if it is free at the hub



Conclusion



Summary

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- **Scenario:** Multimodal hub with PhotoVoltaic production
- **Use:** Design of Public Transport fare and PV surface

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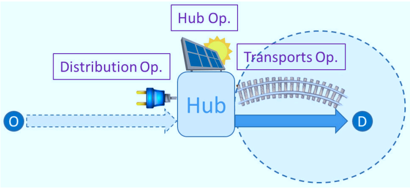

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Perspectives

- EV choose charging need and departure time
- Accurate model of electricity distribution costs
- Definition of operators' utilities and game between them

Appendix 1

Transport mode	Duration	Price	Vehicle class
Public	$\tau_{publ} \times d_{publ}$	$l_{publ}\ m_e\ \lambda_e(x_{e,publ}) + t_{publ}$	EV
		$l_{publ}\ m_g\ \lambda_g \qquad + t_{publ}$	GV
Private	$\tau_{priv} \times \frac{l}{v}\left(1 + 2{x_{priv}}^4\right)$	$l_{priv}\ m_e\ \lambda_e^0$	EV
		$l_{priv}\ m_g\ \lambda_g$	GV