Charging Infrastructure Recommendations for Cities Targeting Full Passenger Car Electrification,

Based on a Case Study of Stockholm County

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EVS35
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Context

- Stockholm aims to enable 100% BEV in city center by 2030
- Cars don’t stay in the city center → regional challenge
- ~1 000 000 cars in region
- Extensive on-street parking
- Congested power grid

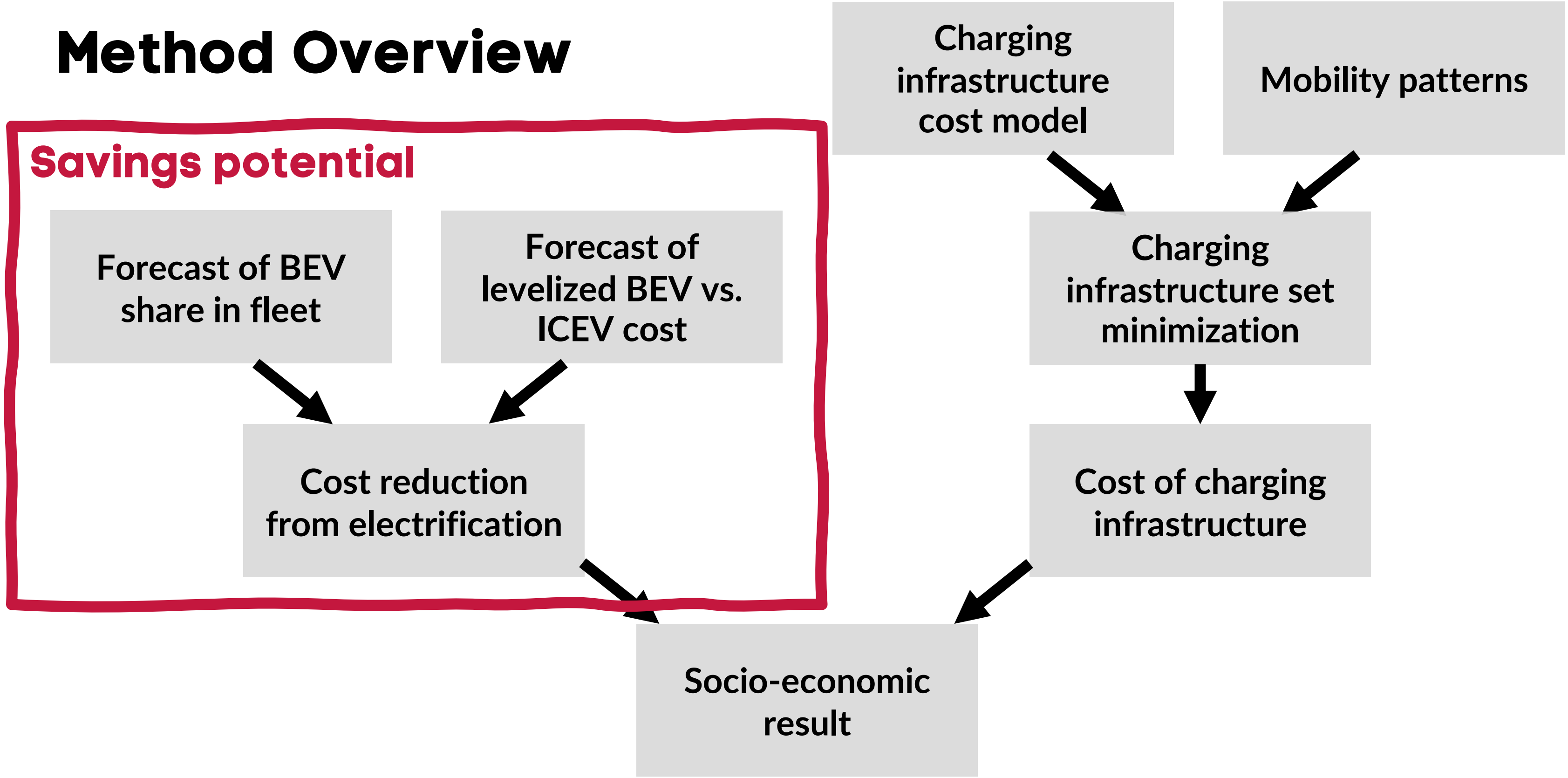
Research Questions

- What is the most cost-efficient **combination** of charging infrastructure to power all cars?
- How will car electrification affect **different population groups**?
- How actively should the **public sector** get involved in charging infrastructure construction?

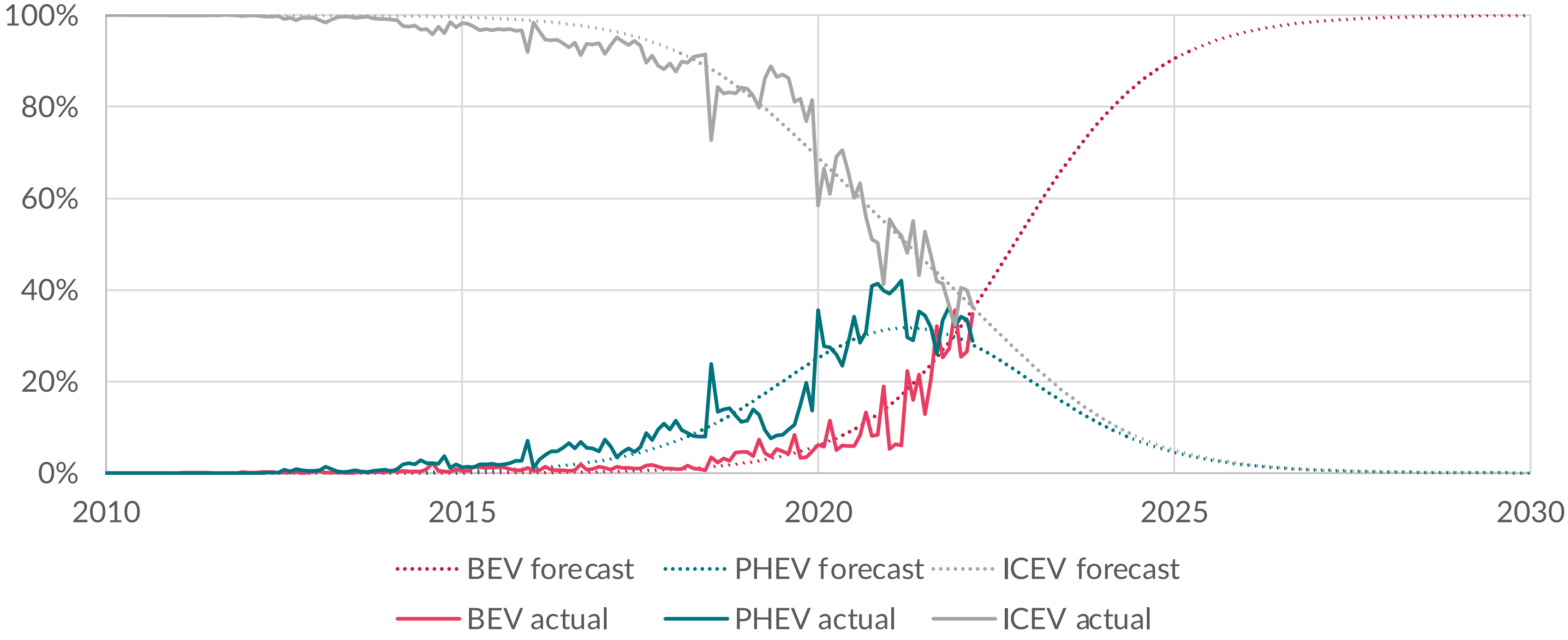
Contribution

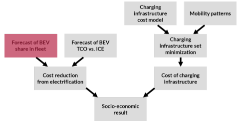
1. **Integrated model** of traffic patterns, charger cost and charger use
2. **Easily reusable tool** to find lowest sufficient density of charging infrastructure for when 100% of passenger cars are electric
3. Cost and accessibility assessments for different **population groups**
4. Comparison of electrification **incentives for public and private actors**
5. Estimation of change in system cost and **opportunity cost of delay**

Method Overview

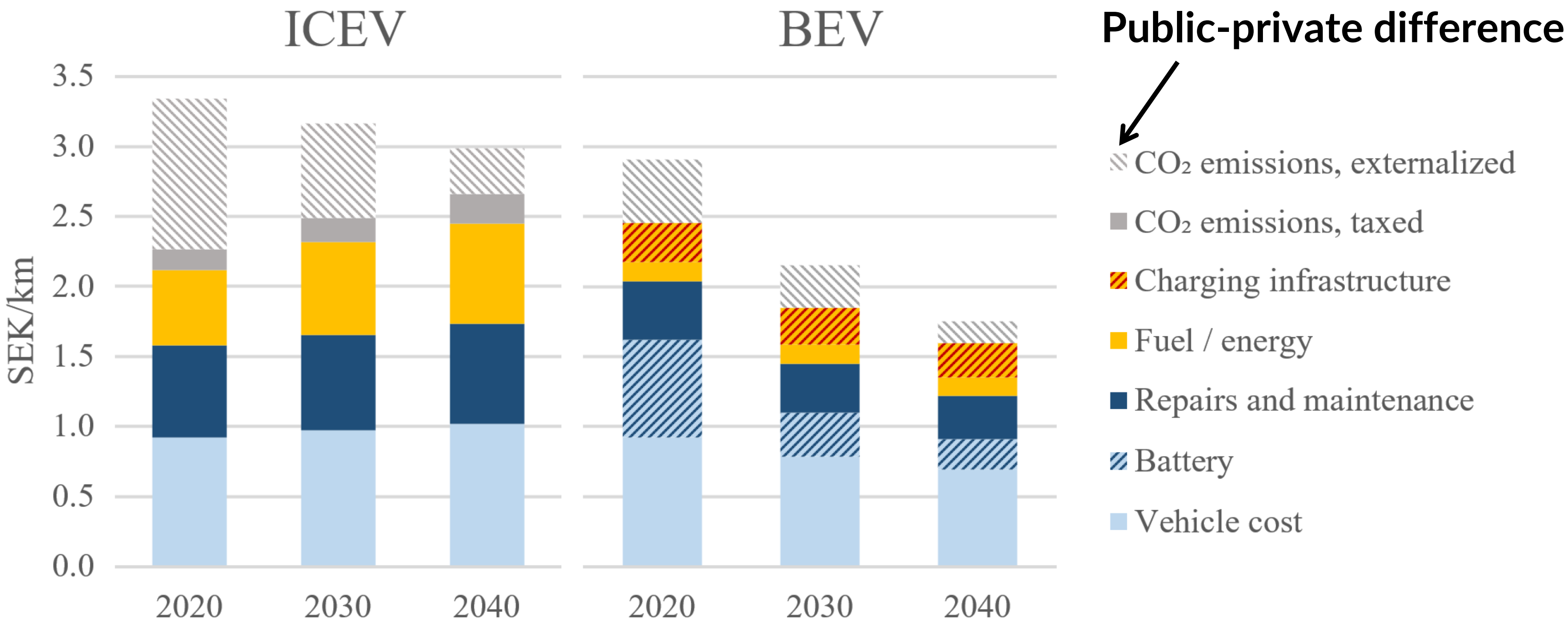


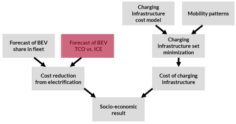
Forecast of EV Sales + Replacement Rate → BEV Share in Fleet





Forecast of Levelized BEV vs. ICEV Cost





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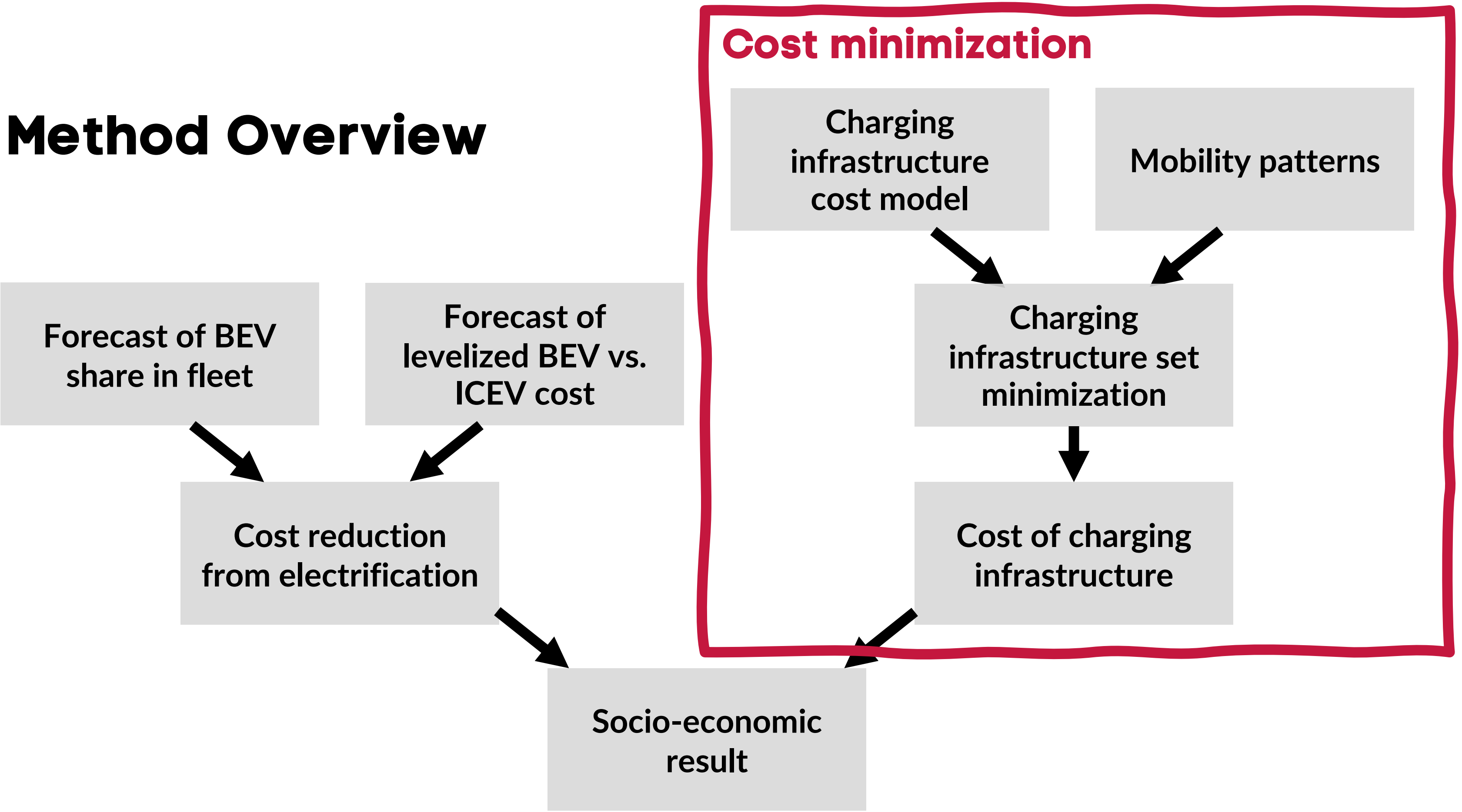
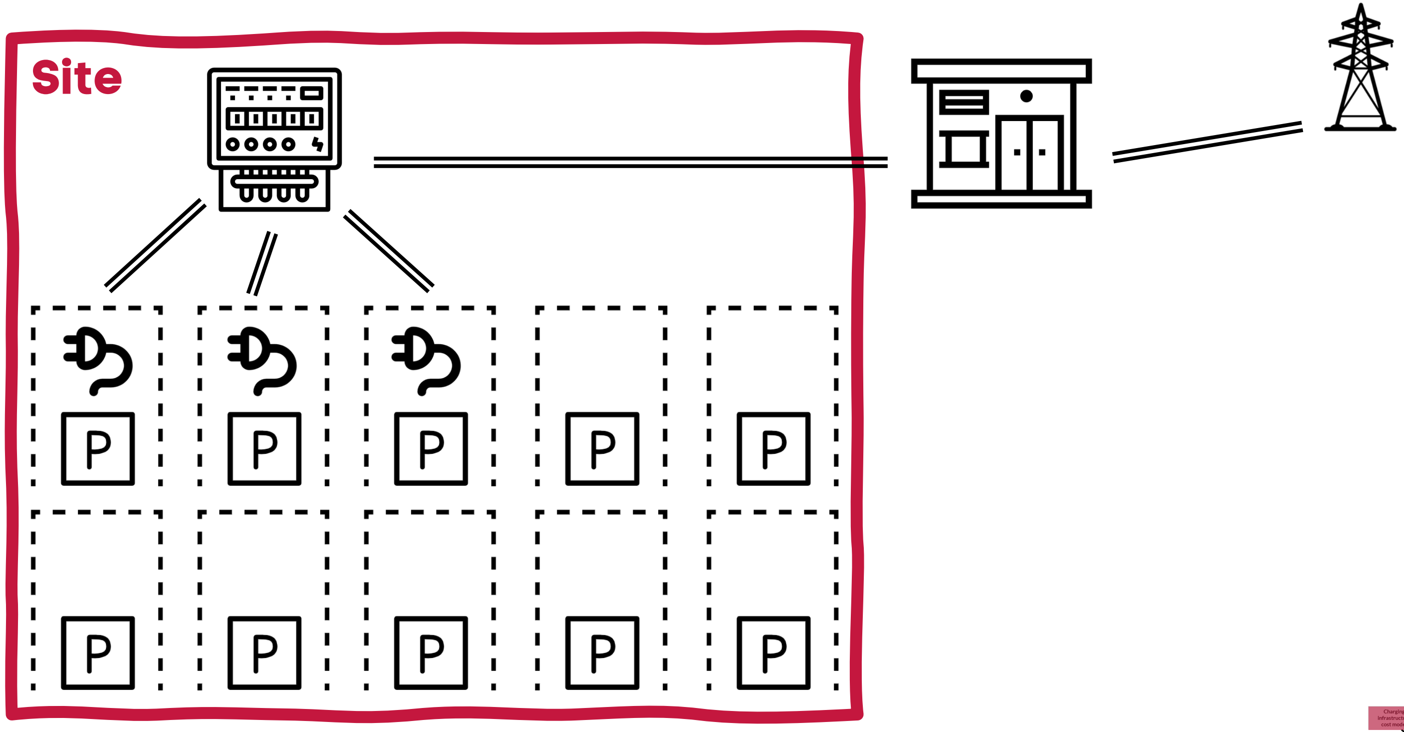
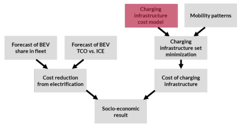


Static Charging Infrastructure Cost Model





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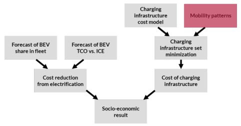
Mobility Patterns Estimated for Stockholm

Adjust to match your city

		Patterns of passenger car use				Leisure time trips to (every n:th day of car use)				
		Night at (default, percent of fleet)	Night in city garage (of days used)	Unused (percent of group, per day)	Commute to (of used cars)	Residen-tial street	Outer city street	Inner city street	City garage, large surface lot	Mall lot
Parking spaces used at night	Single-family home	31%	—	25%	—	1/100	1/14	1/50	1/7	1/7
	Small private garage/lot	17%	—	40%	—	1/100	1/20	1/100	1/14	1/14
	Large lot or garage	17%	—	30%	—	1/100	1/14	1/50	1/7	1/7
Parking spaces used night and day	Residential street	15%	—	55%	3%	1/100	1/14	1/50	1/14	1/14
	Outer city street	7%	1/10	55%	5%	1/100	1/20	1/100	1/7	1/14
	Inner city street	3%	1/10	55%	2%	1/100	1/20	1/100	1/7	1/20
	City garage, large lot	10%	—	55%	25%	1/100	1/14	1/100	1/40	1/20
Parking spaces used during day	Shopping mall lot	—	—	—	—	—	—	—	—	—
	Workplace (small lot)	—	—	—	35%	—	—	—	—	—
	Workplace (large lot)	—	—	—	30%	—	—	—	—	—

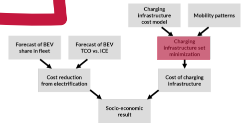


Scenarios for Static Charging Infrastructure

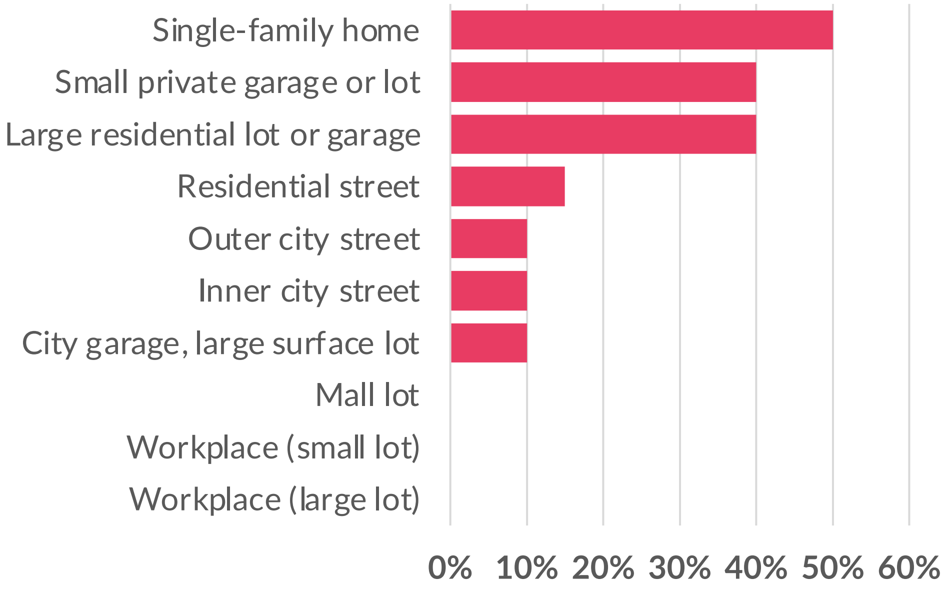
Scenario	Recommended (1)	More street charging (2)	Evenly distributed (3)	Minimal street charging (4)
	Ratio of parking spaces with charging points installed			
Single-family home	50%	50%	50%	50%
Small private garage or lot	40%	40%	30%	35%
Large residential lot or garage	40%	40%	30%	35%
Residential street	15%	25%	10%	15%
Outer city street	10%	25%	10%	0%
Inner city street	10%	50%	10%	0%
City garage, large surface lot	10%	20%	10%	40%
Mall lot	0%	0%	10%	40%
Workplace (small lot)	0%	0%	10%	0%
Workplace (large lot)	0%	0%	10%	0%
City garage visit fq. (of days used)	1/10	1/10	1/10	1/4
CAPEX to install all infrastructure (MSEK)	8 406	9 720	10 381	8 848
Levelized cost @ full build-out (MSEK/year)	3 [illegible]76	4 264	3 776	3 605
Daytime energy	15%	24%	28%	29%
Total MW nighttime	643	575	546	532
Total MW daytime	171	259	336	342
Mean SoC on access (resiliency)	77%	85%	77%	77%
Min SoC on access (resiliency)	64%	67%	63%	63%
Mean SEK/kWh, excl. tax (infra. + energy)	0.9	1.1	1.0	0.9
Max SEK/kWh, excl. tax (low vs. avg is fair)	1.7	3.3	1.7	1.7
Eqv. mean SEK/liter, incl. tax	10.1	11.4	10.7	10.5
Eqv. max SEK/liter, incl. tax	14.6	23.8	14.9	14.6

Scenarios

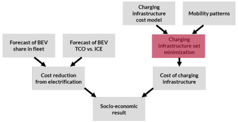
Metrics



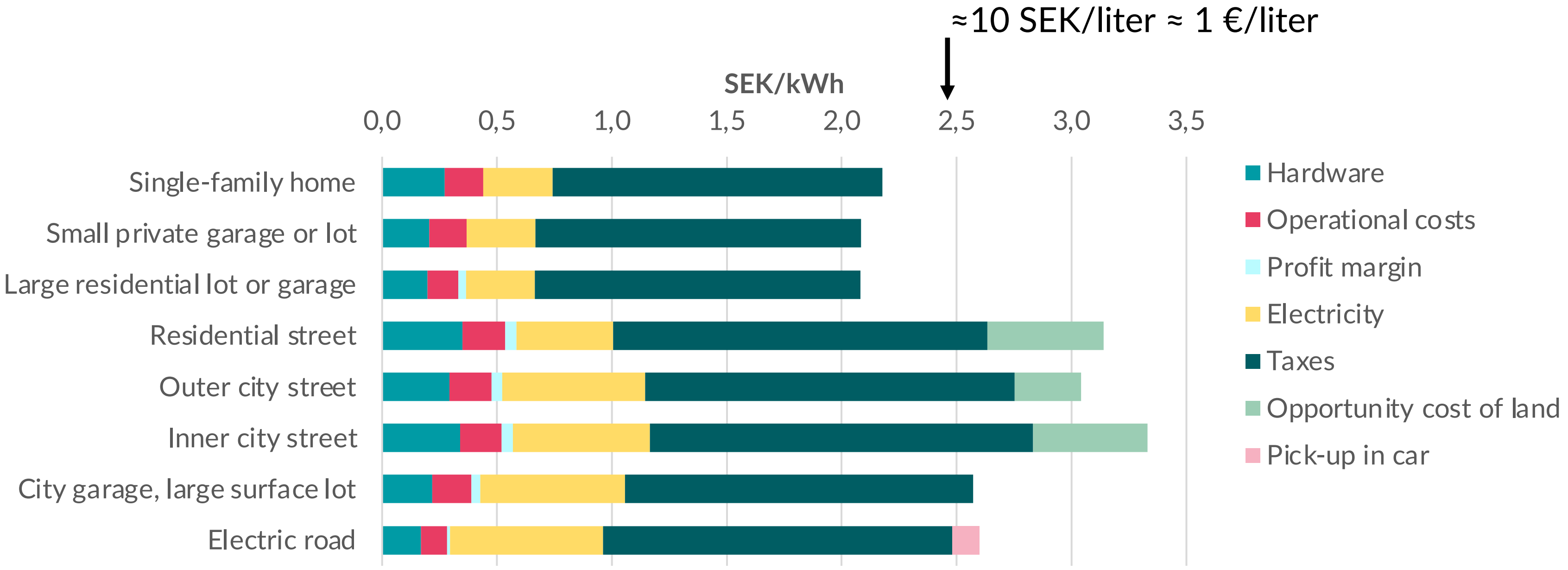
Recommended Charger Density

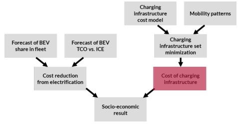


- ✓ Low day-time grid load
- ✓ Low charging cost
- ✓ High SoC
- ✓ Fair
- ✓ Requires booking system



Levelized Charging Cost





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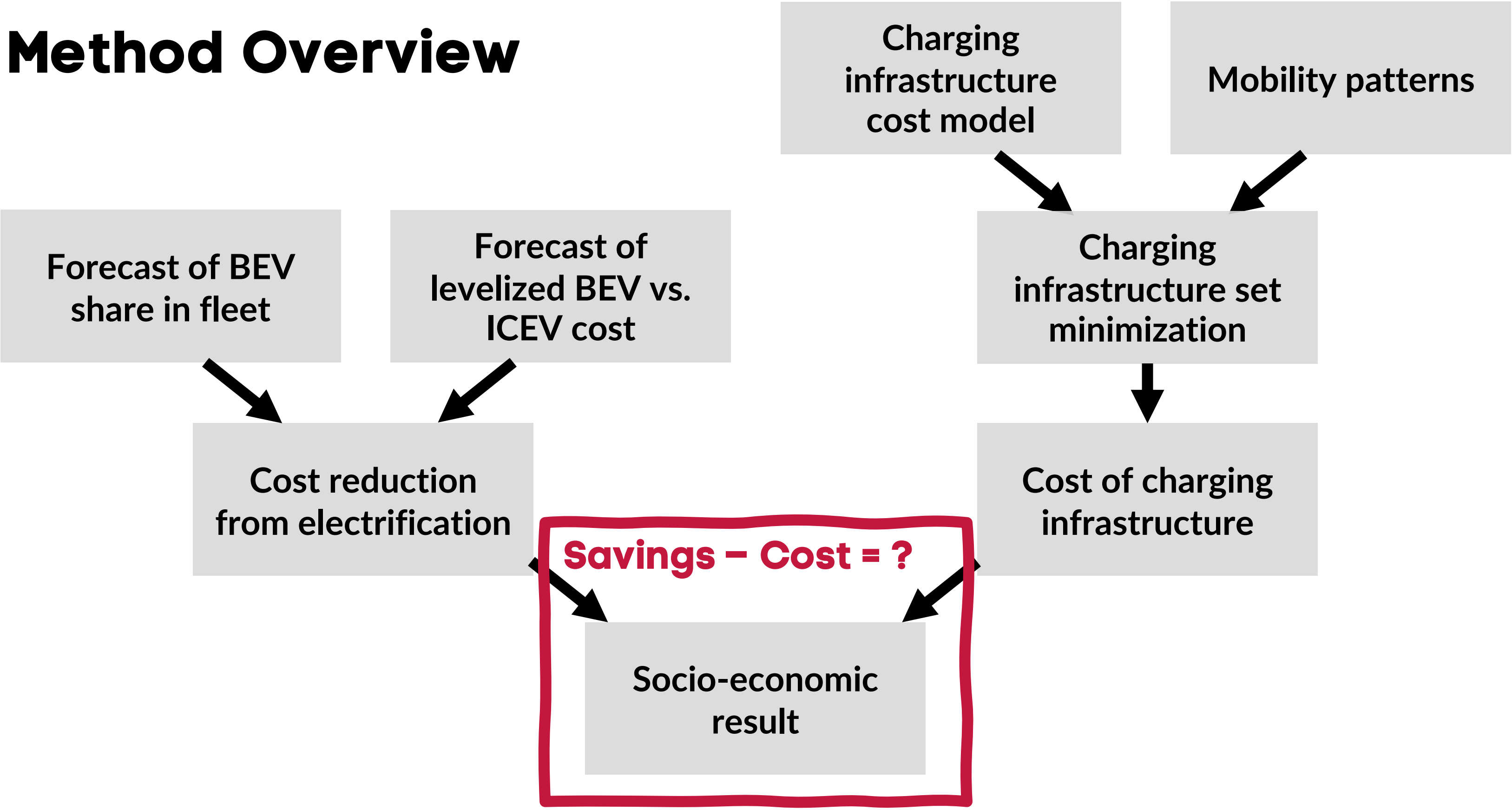
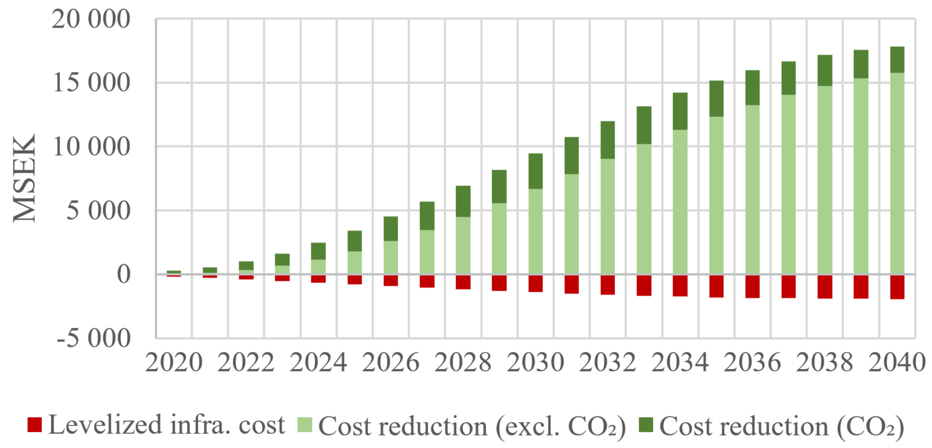
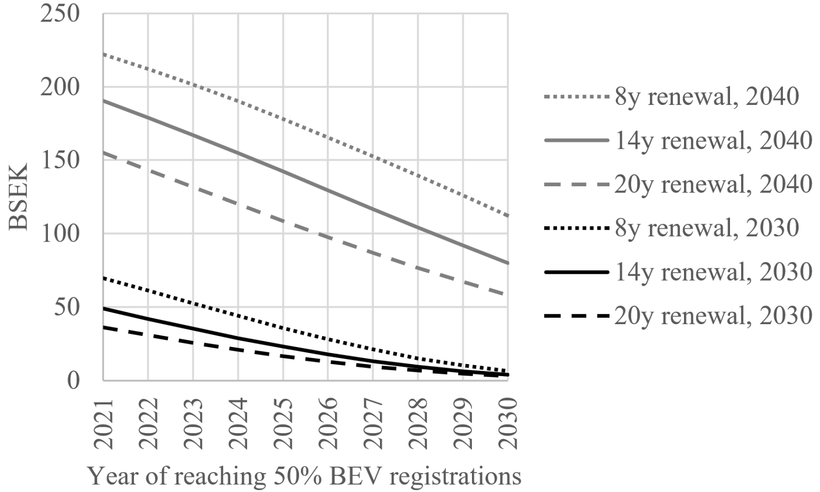


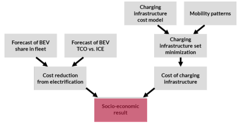
System Cost Reduction vs. 100% ICEV

Annual Difference



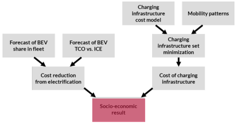
Cumulative Difference





Opportunity Cost of Delayed Electrification

- Total charging infrastructure investment: €0.8b
- Forecast 50% BEV sales by 2030, 14y ICEV lifespan
  → Cumulative savings: €3.5b$_{2020\text{-}2030}$ / €17b$_{2020\text{-}2040}$
- 1y slower to 50% sales, or 2y longer ICEV lifespan
  → €0.6b / €1.2b lower cumulative savings



Urban electric roads?

Pros

+ Lower deployment cost than static charging
+ Similar accessibility and cost for all
+ Cars, buses, taxi, light & heavy trucks
+ Encourages high vehicle utilization
+ Quicker to 100%?

Cons

– High day-time load on grid
– Lack of standards / few suppliers
– Less mature technology
– Low public support(?)
– Slower to 20%

Recommendations for Cities

- Prioritize fast over cheap
- Incentivize early ICEV retirement
- Subsidize, invest, or tax emissions, for a level playing field against ICEV
- Minimize day-time static charging
- Introduce dynamic grid fees

- For on-street parking spaces, chargers at 10-15% is enough
- …with a booking system for chargers, and back-up from public garages
- >10% of on-street parking spaces
  → Save money by charging from below

Try the tool! (MS Excel)

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