Circumventing Limitations to Transport Energy Efficiency – The Electric Car in two-car Households

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Highlights

The driving in 2-car households makes it possible to on average

- achieve roughly **70% more BEV driving** (compared to 2nd car replacement only)
- **while avoiding almost all unfulfilled driving** (due to range and charging limitations)
- with a **smaller battery**
- **=> a present value of ≈$7000** ($2000 - $11000)
- turn the **BEV into an economically viable option in two-car HH** (at estimated mass production costs)
- **replace electricity for fuel competitively in car transport**
- **increase** the **fuel replacement factor** (saved fuel/electricity input)

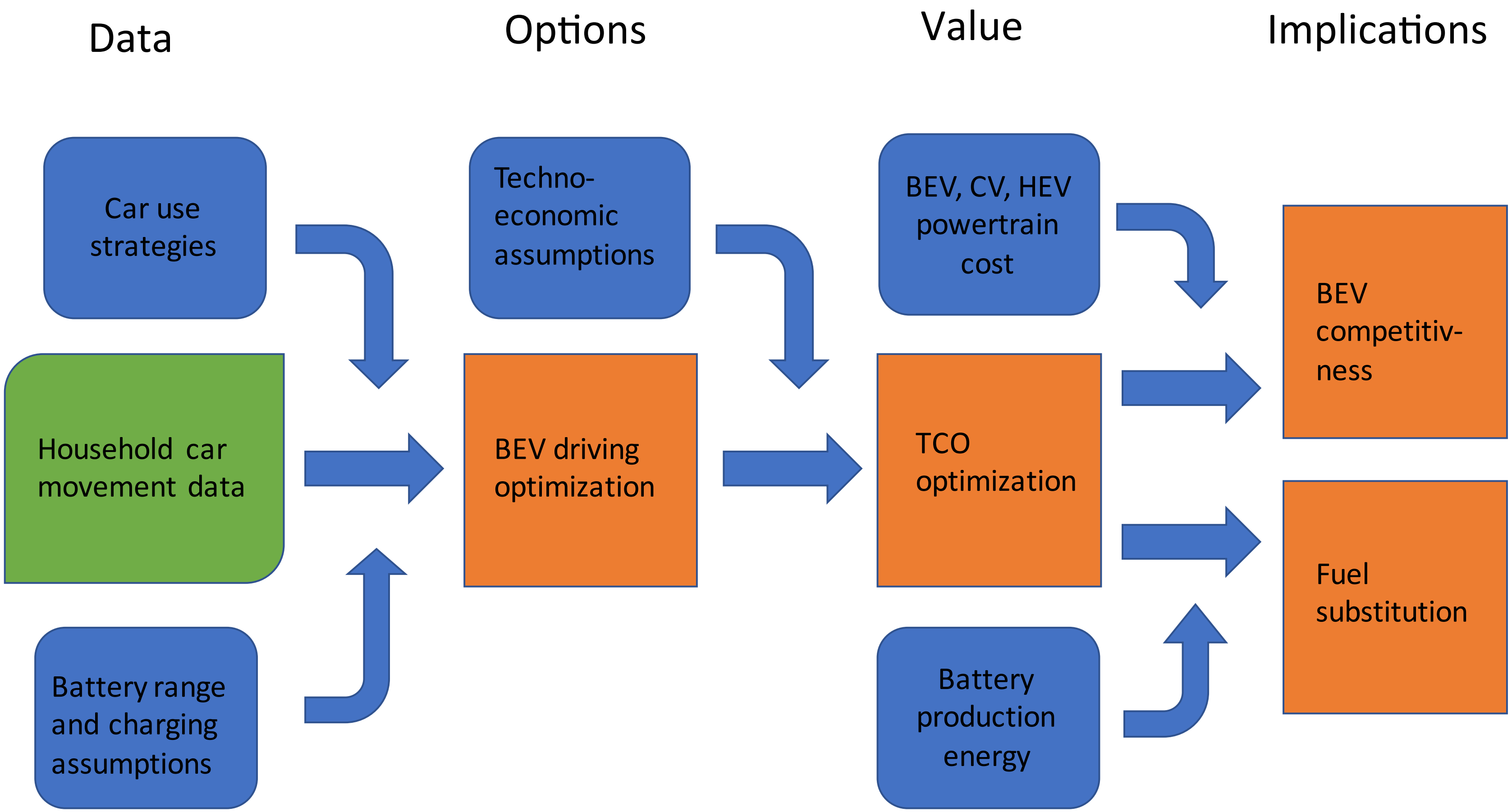
Further BEV deployment?

- ***Low operational, but high investment cost (esp. battery)***
- ***Range (and charge) limitations***
- ***=> earlier: BEV = city car, second car***

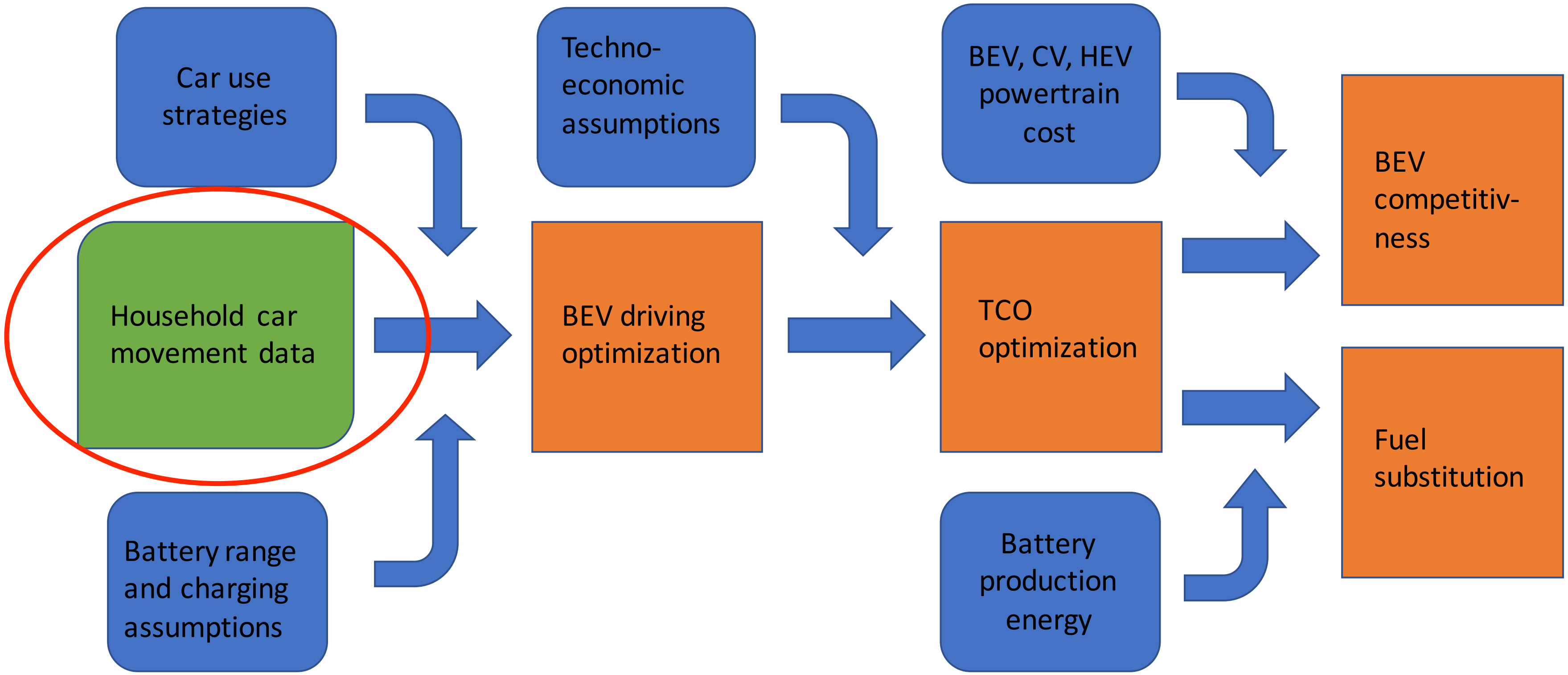
Beyond early adopters (often fleet/company vehicles)?

- Private households with
  - **many vehicles** (may **circumvent range limitations** by choice of car)
  - Also commuting (high annual VKT to pay for high investment cost)
  - home charging option
  - money (mostly only new BEVs available)
- Have been early recognized, but lack of data

Study overview

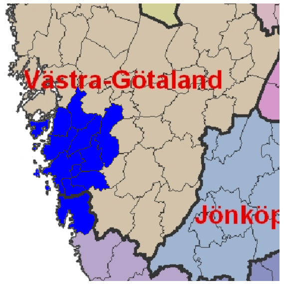


Car movements



GPS logging of two-car households

- HH in Gothenburg regions, random, 2 private cars
- my2002+, ≤ 2000kg, ≤200kW,
- ≤ 65 yrs old, ≥ 2 “active” licences
- commuting 10+ km one-way

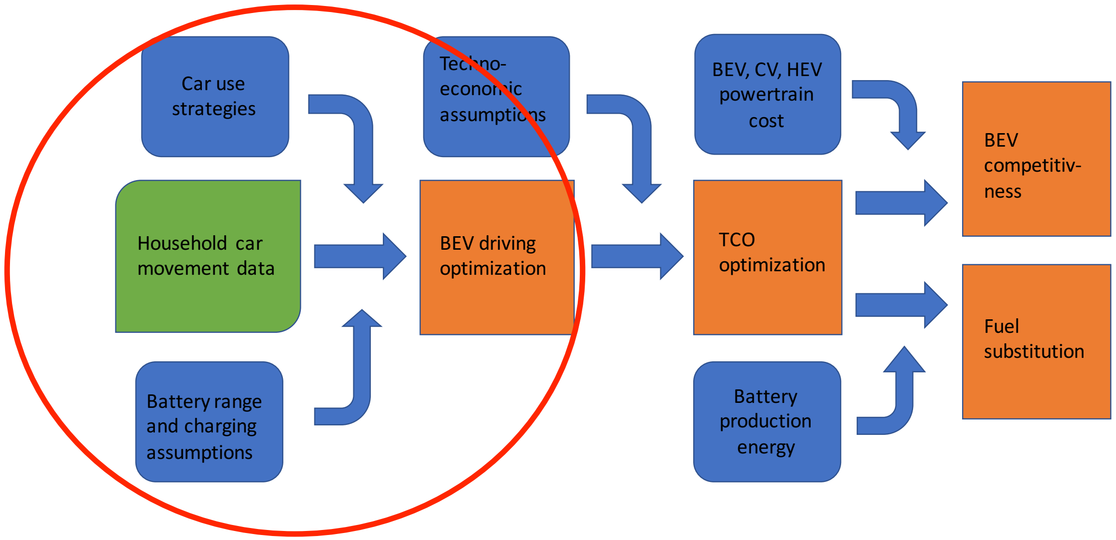


We have:

- both cars in 64 households, simultaneously ≈ 2 months, 2013-14

How much BEV driving is physically attainable?

- movement patterns
- car use strategy
- range and charging limitations

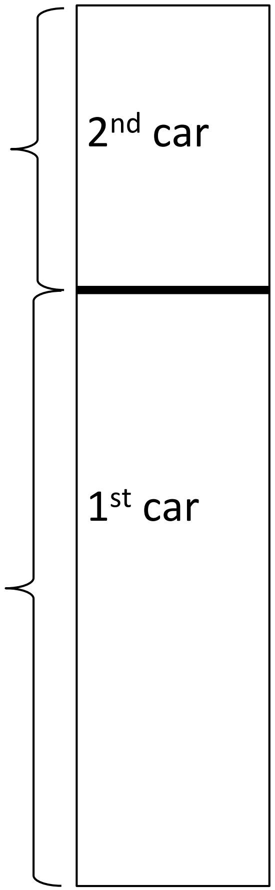


How much is physically attainable for a BEV?

- 3 basic strategies
- without range and charge limitations!:

Car2 =
replace only 2nd car
max **38%**

Car1
max **62%**



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- 3 strategies
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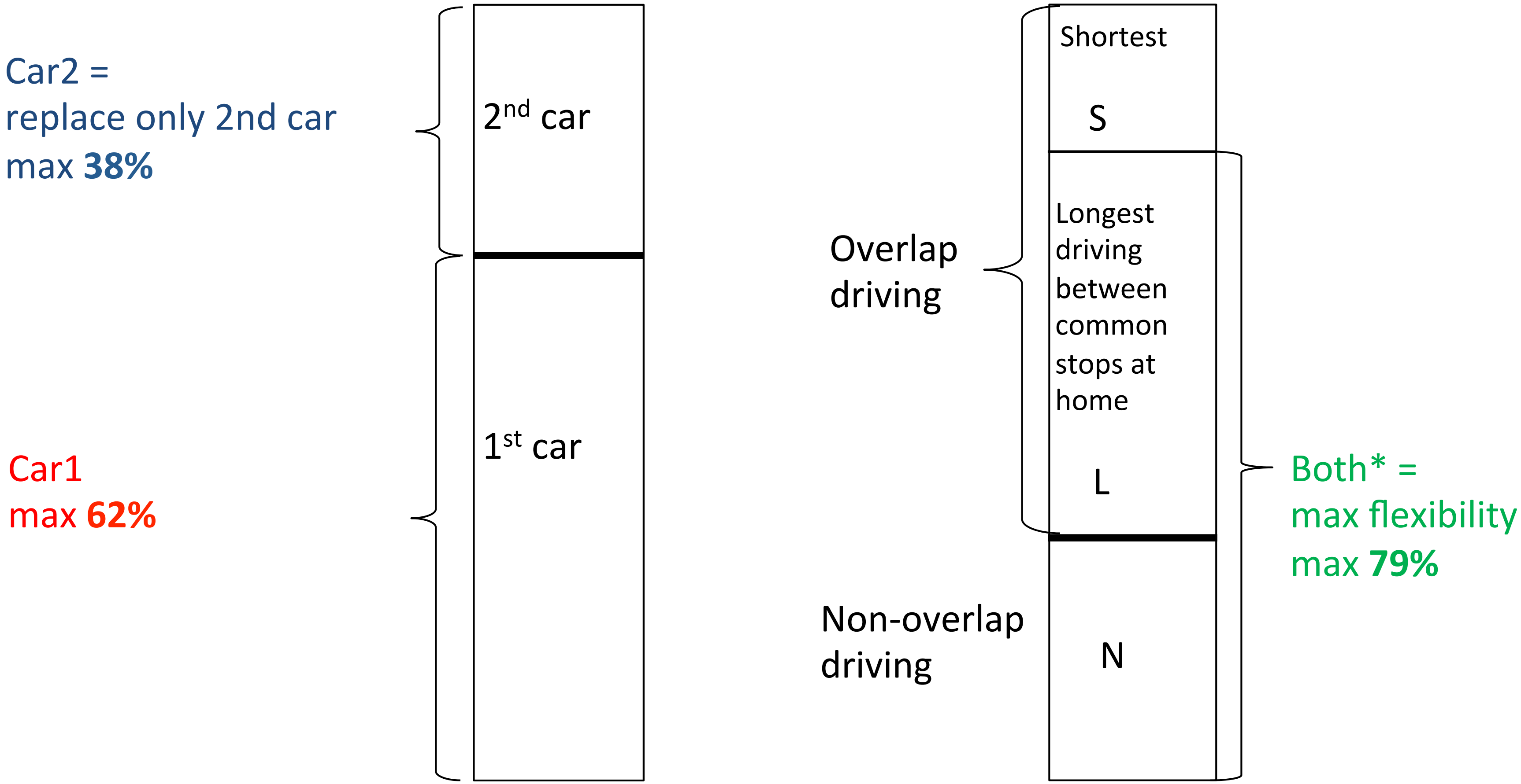
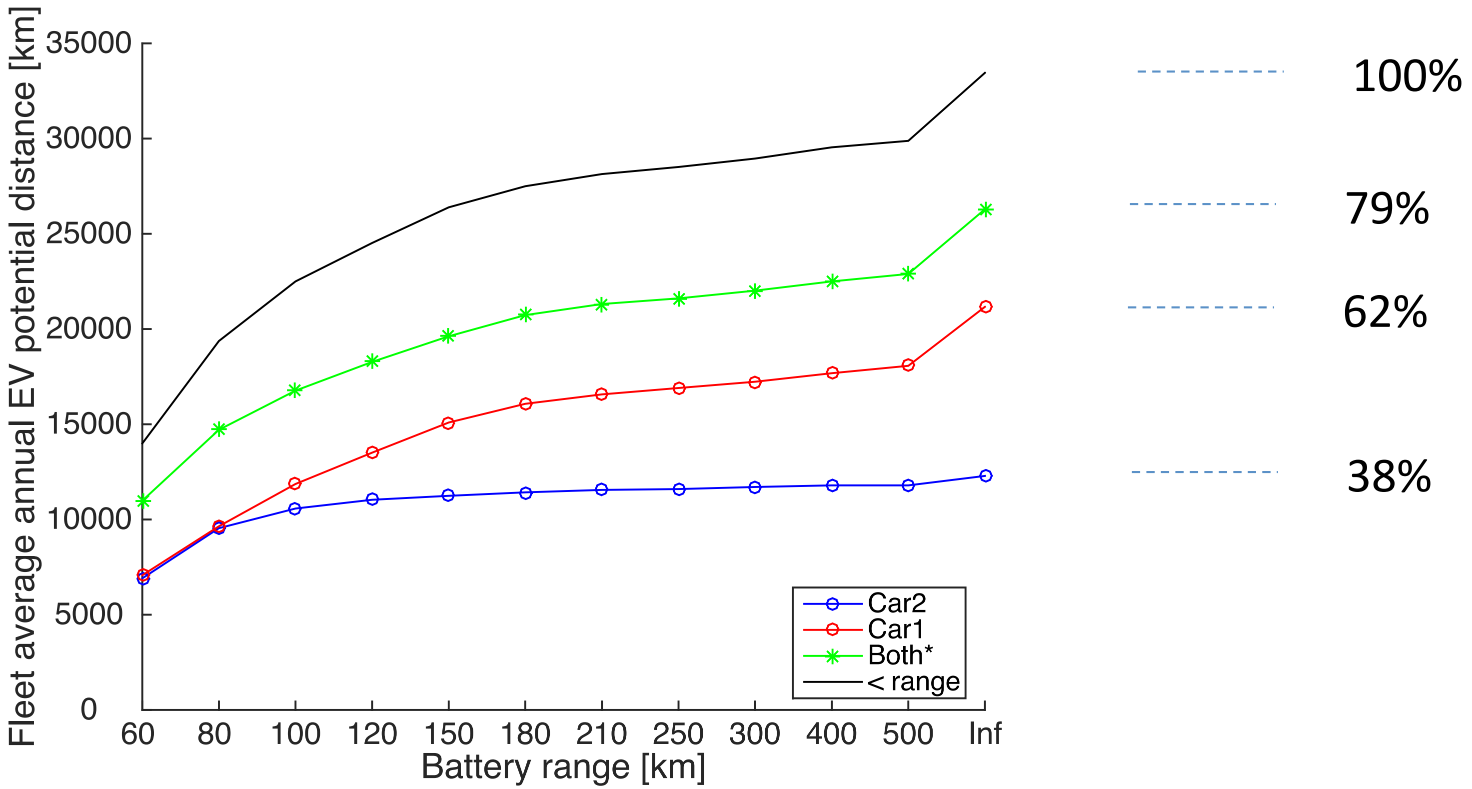


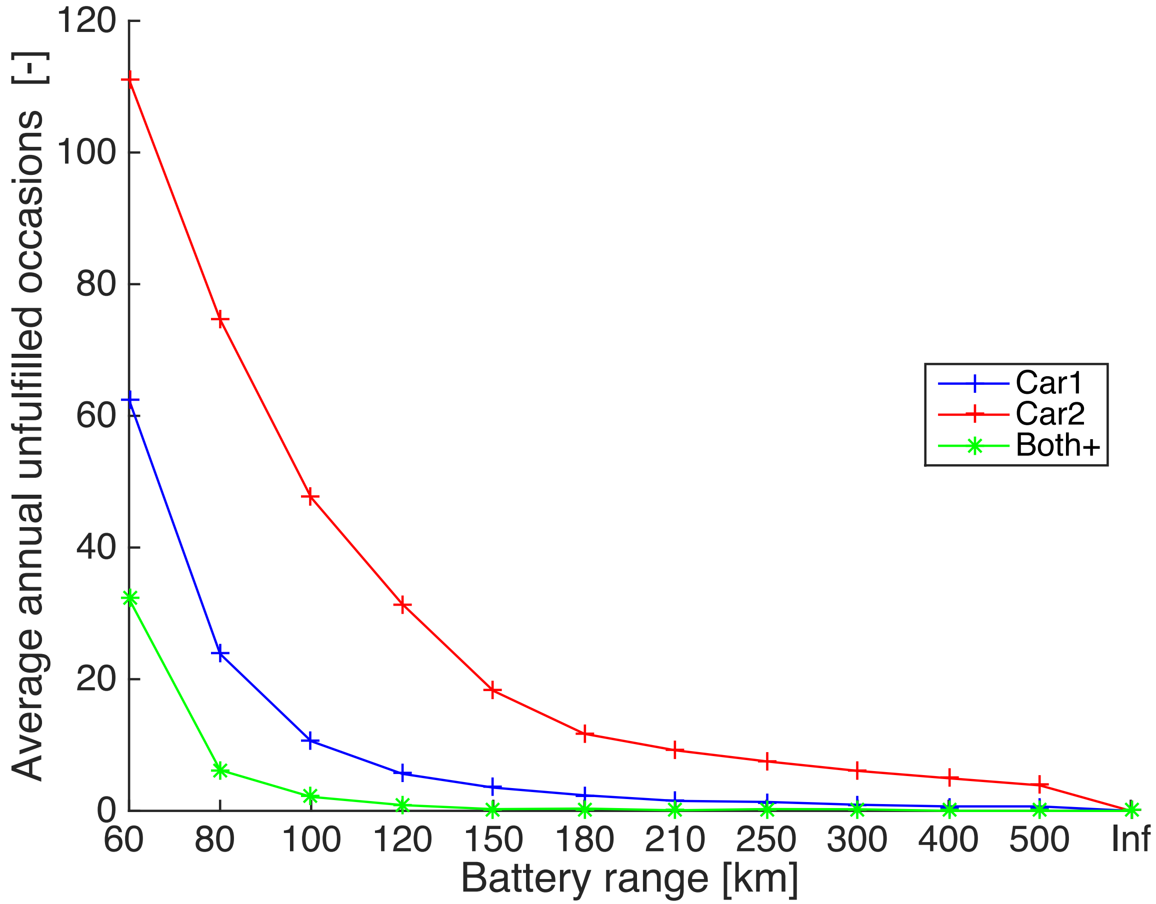
Potential BEV driving with range (at charging = 3 kW)

- **Car2 –> Both* : Around 70% increase of the potential BEV driving**
- 33 –> 55 % of total driving or 11 000 –> **18 300 km/yr at 120 km range**
- ≈ ¾ of the household hth-trips below range possibly reached by an BEV



…. combined with less unfulfilled driving!

- Car2 << Car1
- Both*: Possible to avoid almost all of the limitation
  (at current range and charging power)

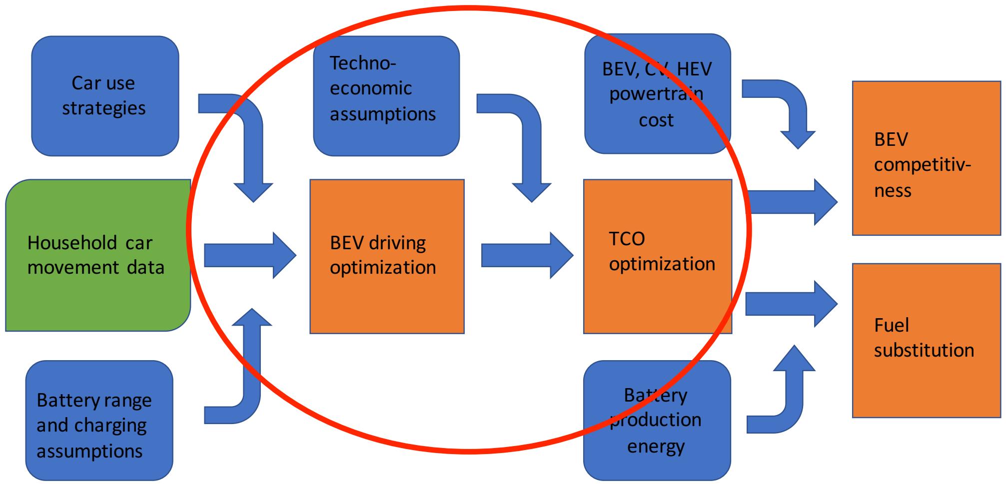


The value of the flexibility – economic optimization

- Maximize gain (vs range) in **total cost of Ownership (TCO)**

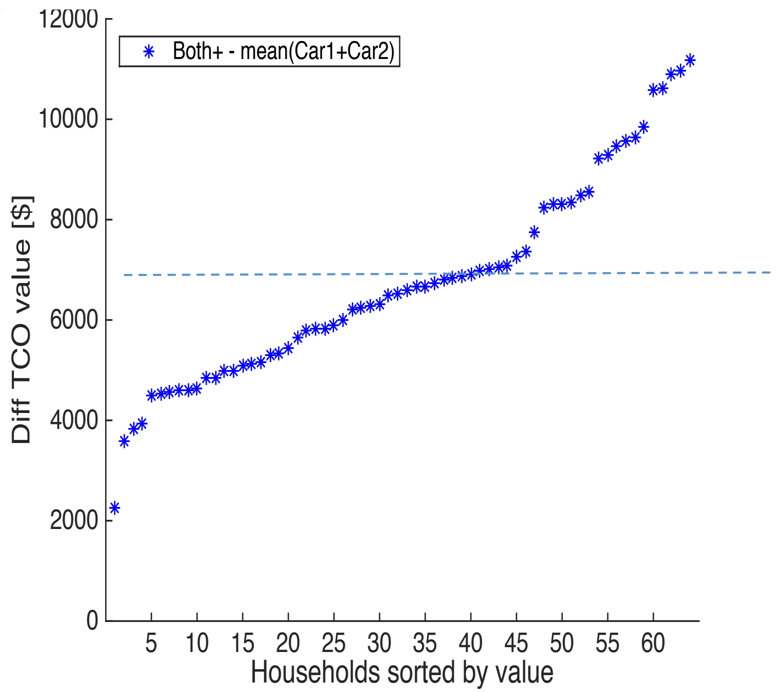
Composed of: Assumed values

+ Energy cost savings when driving electric	Electricity and fuel price	0.2 $/kWh
	Specific energy use	0.2 and 0.6 kWh/km
– Battery investment costs (annuity 15%)	Battery specific marginal energy cost	**300 $/kWh**
– Cost for unfulfilled driving	Extra cost for unfulfilled trips	**50 $/occasion**



Present value of the flexibility in two-car households

- ≈ $ 2000 – $11 000 per household

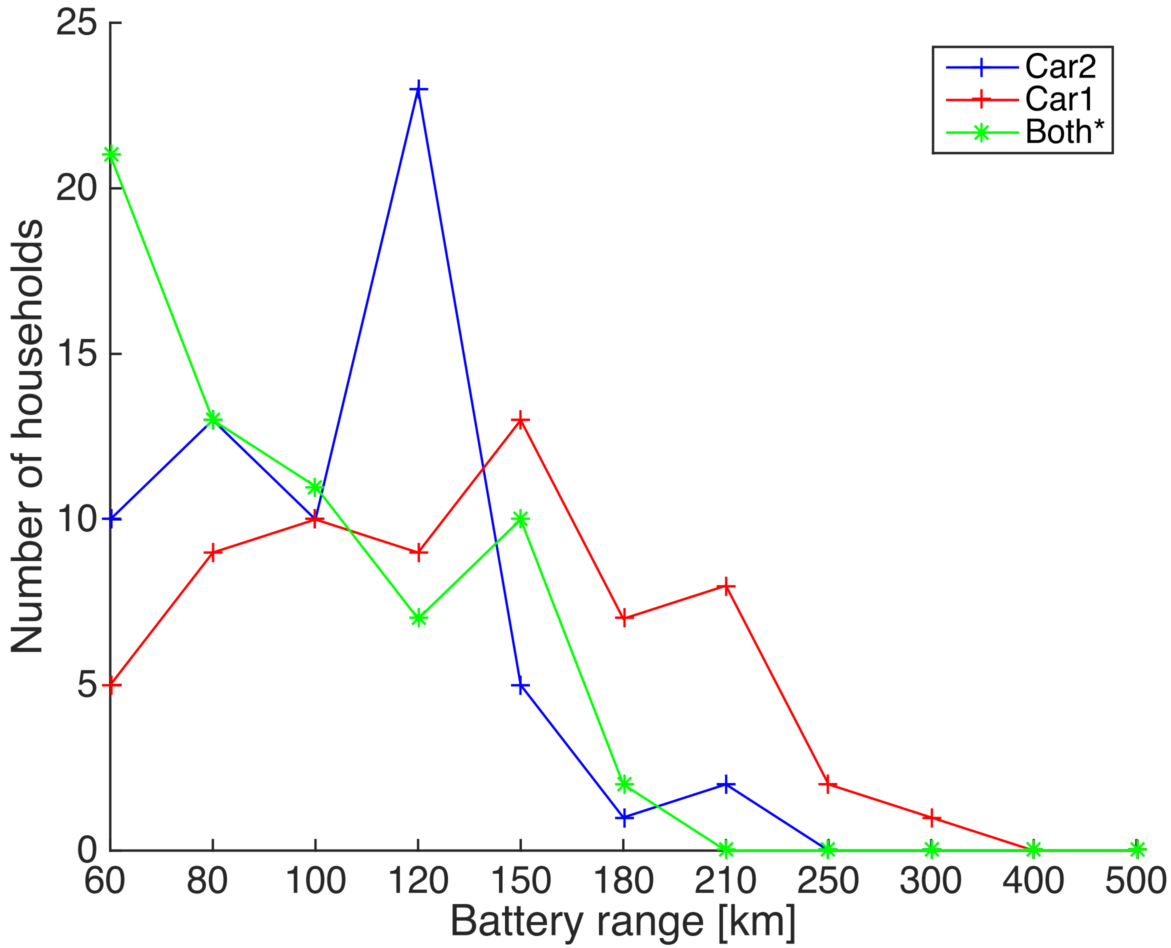


$6700 on average

Present value for individual households

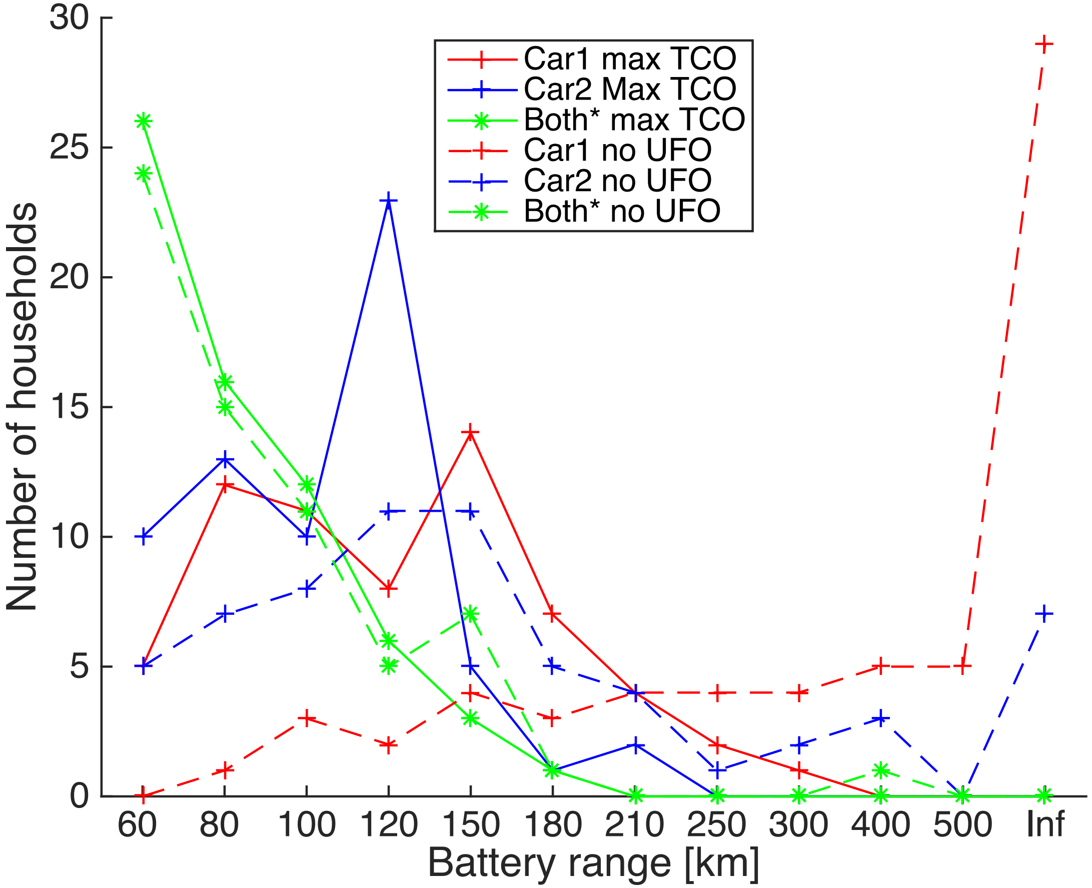
… achieved with smaller optimal battery ranges

- Both* < Car 2 < Car1 (on average)



Battery ranges: optimal and for no unfulfilled driving

- No unfulfilled: Both* << Car1, Car2

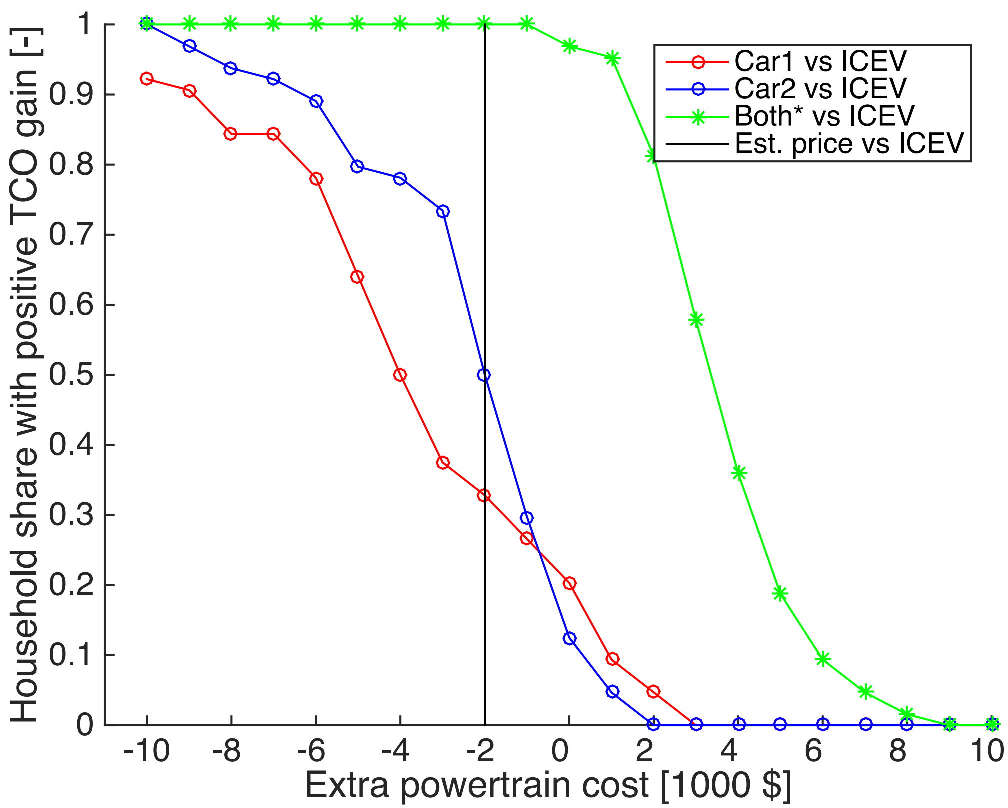


Implications I: BEV competitiveness?

- At mass production: BEV $2000 cheaper than ICEV (for instance, ANL 2016)
- Battery: $300/kWh

⇒ 30-50% –> 100%

- Same compared to HEV (more fuel efficient but also more expensive)



Implications II: Fuel replacement

Assumptions

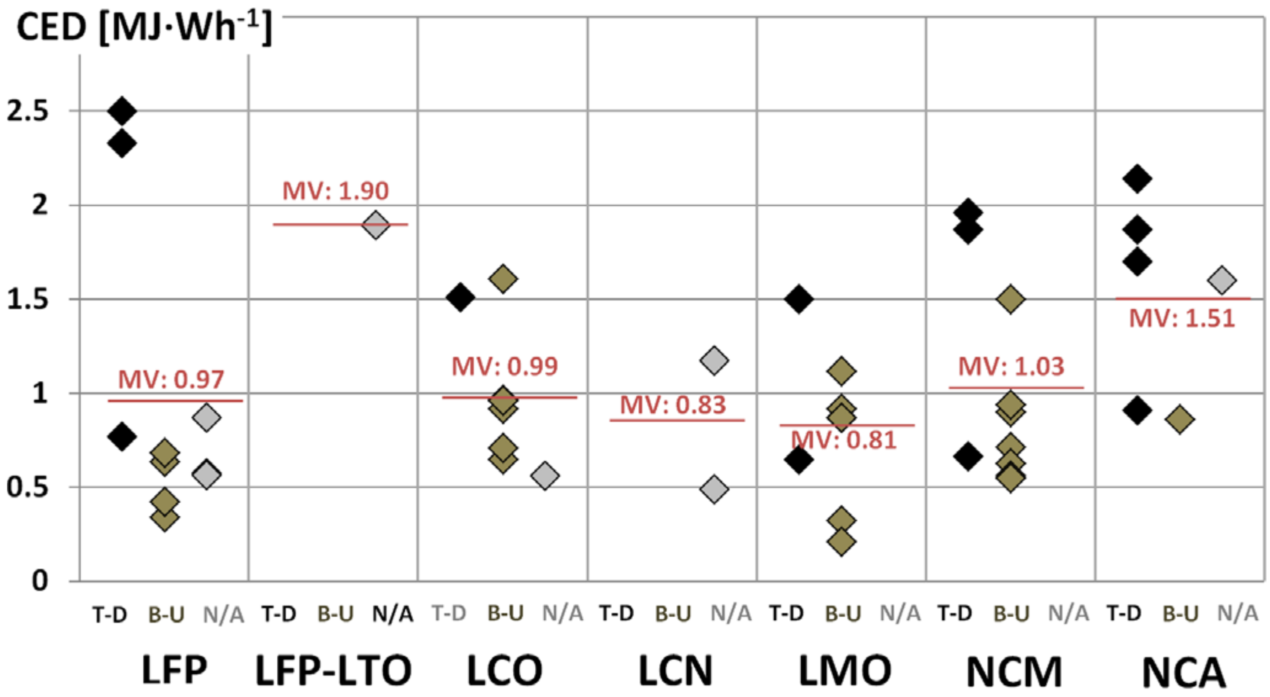
- Direct energy for propulsion: **fuel 0.6 and el 0.2 kWh/km**

- Indirect fuel for electricity
    - totally dependent on el production: CO_2 for BEV: 0 —> >100% of ICEV
    - Sweden: expansion due to **BEVs ≈ 0**

- Battery production a considerable life cycle energy cost (several LCI −studies)
- Difference BEV − ICEV: due to battery (≈ 80%)
- Energy for battery production (CED) **300 kWh fuel/kWh battery** (next slide)

Energy for battery production

- Top-down > bottom-up studies (Peters et al 2017)
- Almost all in the form of fuel, little electricity (Notter et al 2010)
- Cumulative energy demand (CED): ≈ 1 MJ/Wh = 278 kWh/kWh (Peters et al 2017)



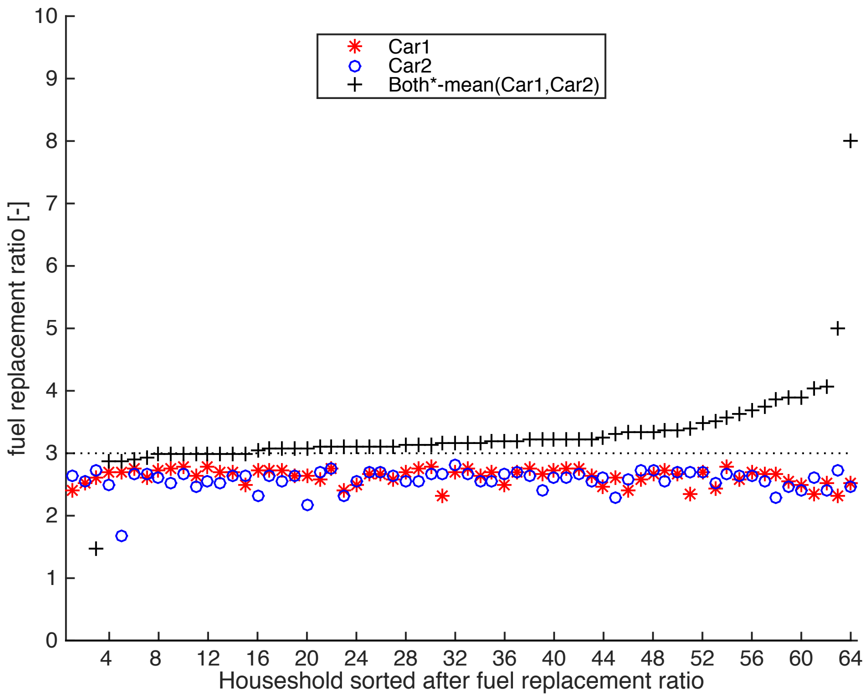
Assumed

Peters et al 2017

Fuel replacement factor

- **FRF = saved fuel/electricity input**

➢ **The flexibility gives a marginally increasing fuel replacement factor (saves further fuel with a smaller battery)**



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Thank you for your attention !

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Also: Karlsson S, 2017. What are the value and implications of two-car households for the electric car? *Transportation Research Part C* 81, 1-17. (Open access article)

A note: BEV cost current status vs mass production

Current Swedish prices (for same car but different powertrains)

	BEV – CV alt HEV	Price difference [USD] ([SEK])	Price difference w/o battery at 500/300 USD/kWh [USD]	Estimated price difference w/o battery at mass production [USD]	Current Swedish BEV subsidy [USD]
CV	VW: e-Golf (24 kWh) vs gasoline Golf 1.2 Bluemotion w aut. transm. (DSG)	22 500 (180 000)	10 500/15 300	-2 000	5 000
HEV	Hyundai Ionic ComfortEco: BEV (28 kWh) vs HEV	15 250 (122 000)	1 250/6 850	-5 000	5 000

	"how much too expensive"
VW Golf BEV:	$12-17000
Hyundai Ionic BEV:	$6-12000