# Full Decarbonization of Berlin's Traffic: Simulation Studies and Political Reality

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# How it started (for us)

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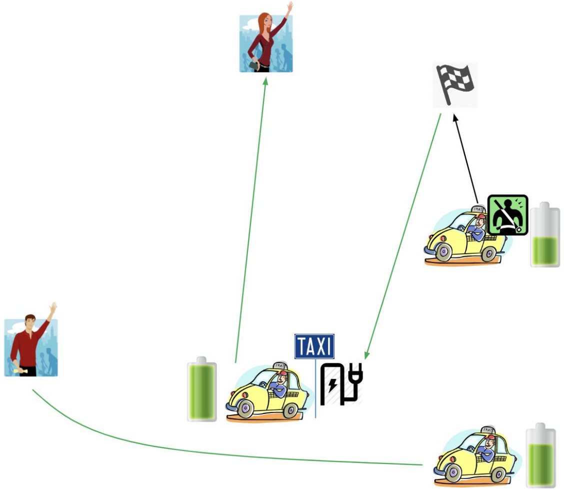
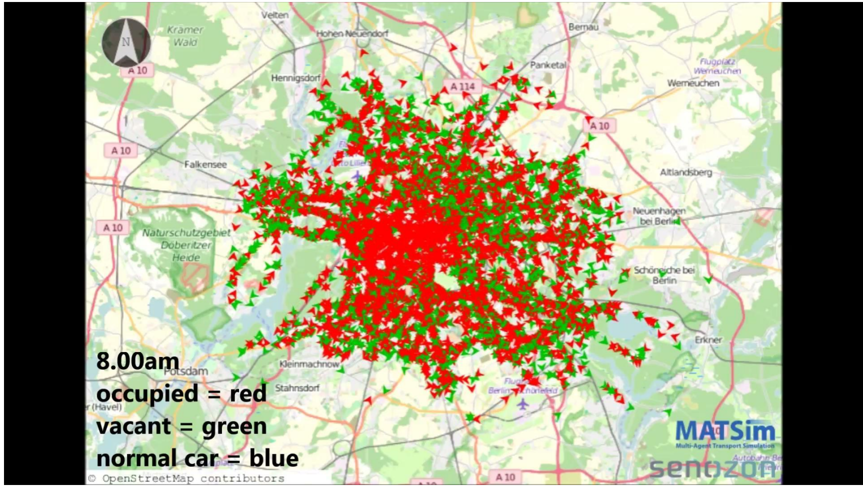
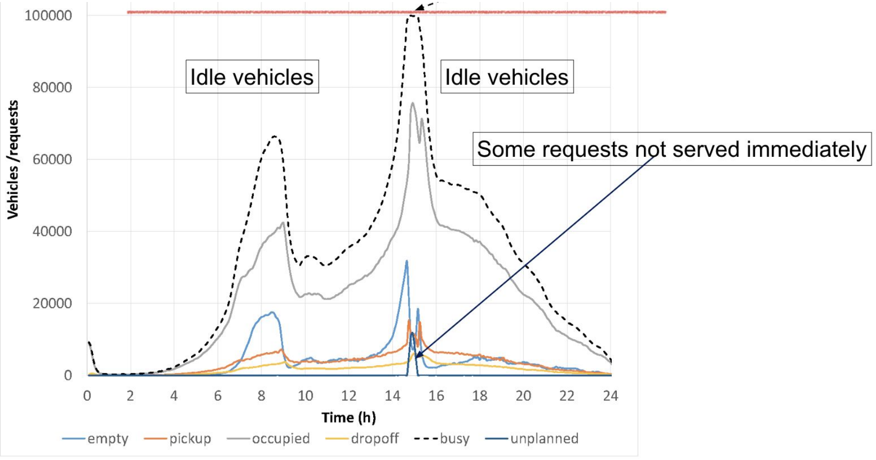
# 2014/15(!): Electric taxis not more expensive than fossil

# Build pickup/delivery model that generates realistic daily vehicle trajectories

1. Create plausible synthetic demand.
2. Have synthetic vehicle fleet serve this demand.
3. Include charging. There is enough time. “Sufficient” number of chargers at taxi ranks.
4. Compute costs (next slide).



# Operating cost el. taxis

Table 5.2: Energy consumption under different scenarios

| Scenario | Standard | Summer | Hot Summer | Winter | Cold Winter | Cold Winter | Cold Winter | Cold Winter |
|---|---|---|---|---|---|---|---|---|
| Busy day | – | – | – | – | – | + | – | + |
| Fossil heating | – | – | – | – | – | – | + | + |
| **Driving** | | | | | | | | |
| Drivetrain [kWh] | 33.75 | 33.75 | 33.75 | 33.75 | 33.75 | 45.00 | 33.75 | 45.00 |
| Auxiliary [kWh] | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| Heating [h] | – | – | – | 7.50 | 16.00 | 16.00 | – | – |
| Heating [kWh] | – | – | – | 15.00 | 48.00 | 48.00 | – | – |
| Cooling [h] | – | 7.50 | 14.00 | – | – | – | – | – |
| Cooling [kWh] | – | 7.50 | 14.00 | – | – | – | – | – |
| Total [kWh] | 41.75 | 49.25 | 55.75 | 56.75 | 89.75 | 101.00 | 41.75 | 53.00 |
| **Charging** | | | | | | | | |
| Speed [kW] | 50.00 | 50.00 | 50.00 | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Vehicle charging time [h:mm] | 0:32 | 0:40 | 0:48 | 1:38 | 2:57 | 3:24 | 1:02 | 1:29 |
| **Chargers** | | | | | | | | |
| Daily charging time per charger [h:mm] | 5:09 | 6:39 | 7:57 | 16:18 | 29:30* | 34:00* | 10:18 | 14:48 |
| Utilisation ratio [%] | 21.5 | 28.0 | 33.0 | 68.0 | 123.0* | 142.0* | 42.9 | 61.7 |
| Dispensed energy per charger [kWh/day] | 257.5 | 332.5 | 397.5 | 407.5 | – | – | 257.5 | 370.0 |
| **Charging costs** | | | | | | | | |
| **Infrastructure** | | | | | | | | |
| per kWh [€] | 0.07 | 0.05 | 0.04 | 0.04 | – | – | 0.07 | 0.05 |
| per min [€] | 0.06 | 0.04 | 0.04 | 0.02 | – | – | 0.03 | 0.02 |
| **Electricity** | | | | | | | | |
| per kWh [€] | 0.20 (all scenarios) | | | | | | | |
| **User costs** | | | | | | | | |
| per kWh [€] | 0.27 | 0.25 | 0.24 | 0.24 | - | – | 0.27 | 0.25 |
| per min [€] | 0.22 | 0.21 | 0.20 | 0.10 | – | – | 0.11 | 0.10 |

**–?? But fuel also ↑ .**

* infeasible charging time

# Annual operating costs battery-electric vs hybrid-electric vehicles

**Table 3** Annual operating cost comparison of BEV and HEV

| | BEV | HEV |
|---|---|---|
| Annual mileage [km] | 75,000 | |
| Energy cost [€] | 4,620 | 6390 |
| Battery cost [€] | 2,500 | |
| Engine maintenance [€] | 150 | 1,000 |
| **Overall operating costs [€]** | 7,270 | 7,390 |

Important: Battery is driven “to the end” → Can thus be allocated to km.

(Often: 400km range, 1000 charging cycles → battery lasts 400’000km!?!?)

Bischoff, J. and Maciejewski, M. (2015) ‘Electric Taxis in Berlin – Analysis of the Feasibility of a Large-Scale Transition’, in *Tools of Transport Telematics*. Springer International Publishing, pp. 343–351. Available at: https://doi.org/10.1007/978-3-319-24577-5_34.

# Electric trash collection (only?) 20% more expensive than fossil

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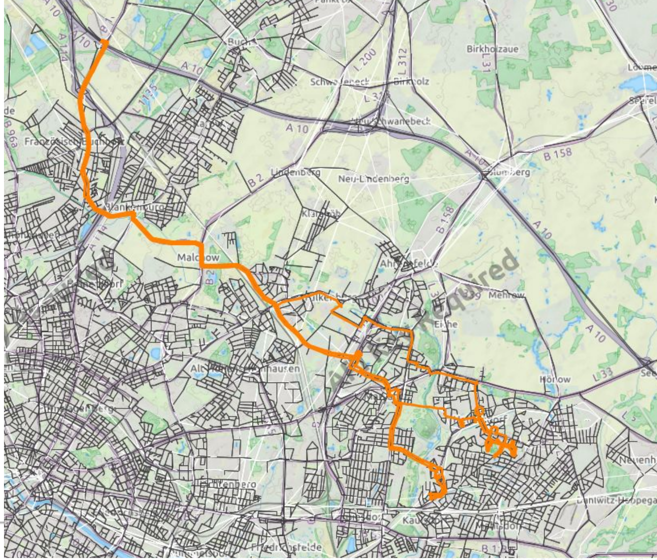
# Build pickup/delivery model that generates realistic daily vehicle trajectories



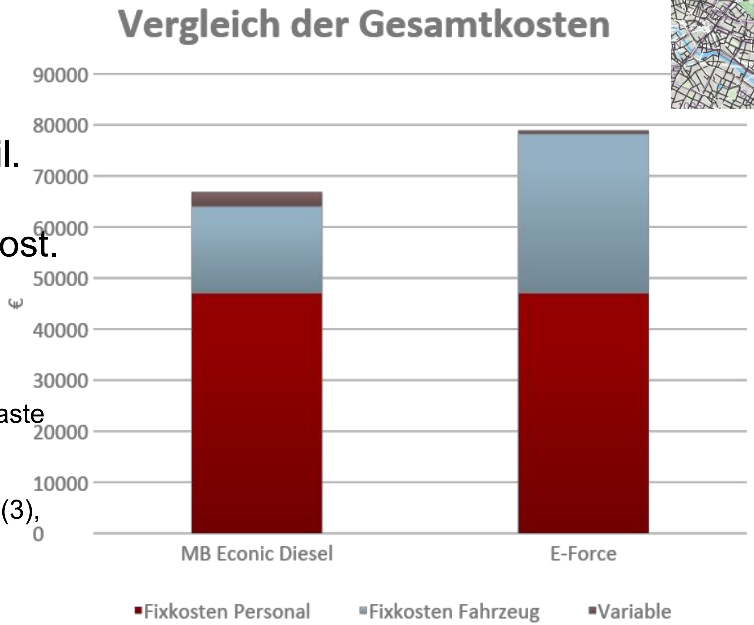
1. Create plausible synthetic demand.
2. Have synthetic vehicle fleet serve this demand.
3. Include charging. Surprise: Overnight depot charging is sufficient.
4. Compute costs.

Vehicle twice as expensive as fossil.

But fossil veh only 20% of overall cost.

80+20 → 80+40 = 120%.

Ewert, R. *et al.* (2021) ‘Electrification of Urban Waste Collection: Introducing a Simulation-Based Methodology for Technical Feasibility, Impact and Cost Analysis’, *World Electric Vehicle Journal*, 12(3), p. 122. Available at: https://doi.org/10.3390/wevj12030122.




# The ZeroC(U)TS project

Zero Carbon (Urban) Transport Systems

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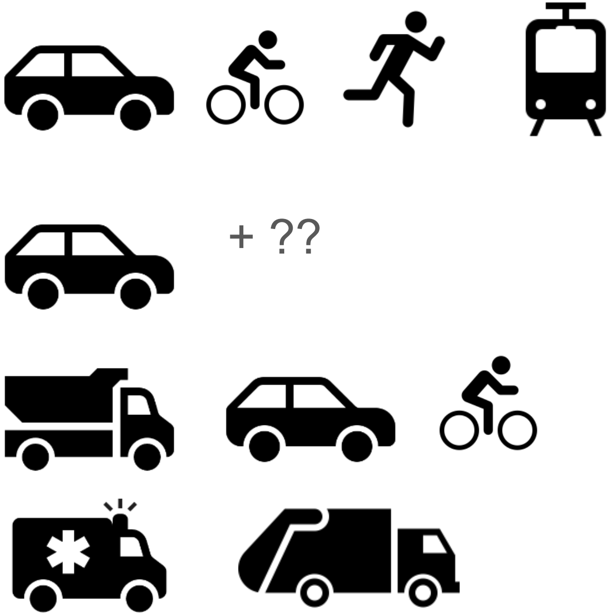
# ZeroCUTS DFG project

With Dietmar Göhlich, Methods of product development ← Vehicle specifications

Göhlich, D. *et al.* (2021) ‘Integrated Approach for the Assessment of Strategies for the Decarbonization of Urban Traffic’, *Sustainability: Science Practice and Policy*, 13(2), p. 839. Available at: https://doi.org/10.3390/su13020839.

Segments of urban traffic:

- Private person traffic
- Commercial person traffic
- Goods traffic
- Other traffic
  (emergency vehicles, city cleaning, …)

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# Non-fossil energy solutions for vehicles

| | Comments | Disadvantages |
|---|---|---|
| **Electric batteries** | Technology available | • depends on electricity mix (now?  2030?)<br>• limited production capabilities (currently 1% of fleet per year)<br>• infrastructure (charing) |
| **E-Fuels** | Infrastructure + vehicles already there | • 4x more sustainable electricity necessary<br>• political dependence<br>• more importantly needed for decarbonization elsewhere (e.g. high-temperature industrial processes, long distance flights)<br>• emissions (besides CO2) same as fossil |
| **Hydrogen** | | see e-fuels, plus:<br>• additional infrastructure |
| **Fuel cells** | Drop-in replacement for electric batteries | see hydrogen |

To me, looks like “electric”, but following material also works for other non-fossil drives.

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# Decarbonization solutions for “other traffic”, “freight traffic”, commercial person traffic

**“Other” traffic:** Emergency services eFuels or hydrogen or fuel cell, everything else battery-electric (~ 20% more expensive, see above).

**Goods traffic:** Collection, distribution: battery-electric. Main haul: Road: battery-electric, maybe overhead lines. Fuel cells? eFuels/hydrogen?? Rail … ~ 20 to 25% (in Germany)

**Commercial person traffic:** Mostly electric …

Not very controversial in citizen council.

Not very controversial with lobbyists.  They demand:

- credible very fast build-up of charging infrastructure
- regulation such that fossil competition not cheaper

Procure test vehicles, then decide.  Eg. BVG Berlin public transit provider …

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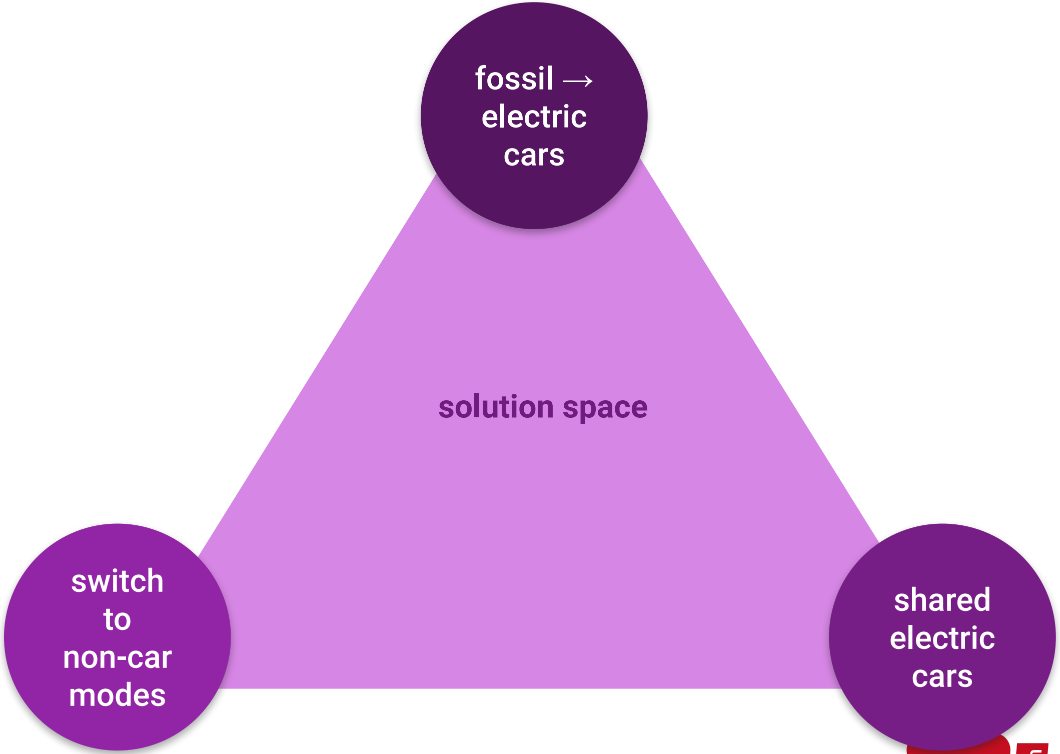
# Person traffic (private, commercial)

Three corner case solutions:

- fossil car → electric car
- switch to non-car modes
- individually owned → shared (electric) car

Presumably need mix of these.
Presumably different for each location.

So far, decarbonization of (urban) traffic looks like a solvable problem.

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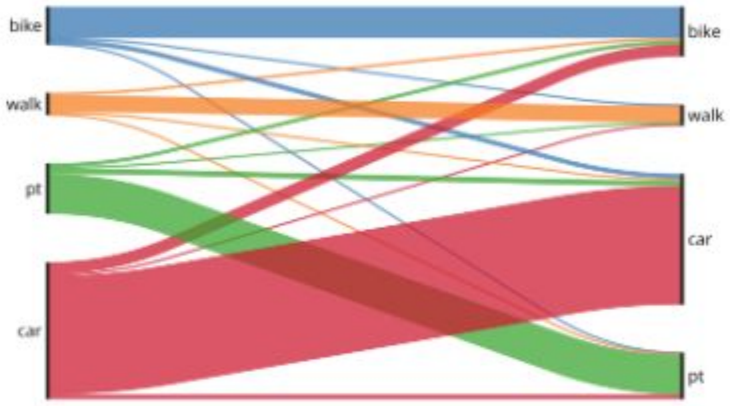
# There is a dream …

(= Sounding board project)

# There is a dream …




… in Germany that improving bicycle infra and public transport will “solve” both the decarbonization and the “car” problem.

*However*, our simulations show that, even if well executed, each of them never reduces car by more than 10%. (E.g. 30% → 27%.)

Need additional “push” measures, e.g. toll agains (fossil) vehicles, parking fees against (fossil) vehicles, zero emissions zone, …

Kaddoura, I. *et al.* (2020) ‘Verkehrsmodellierung für das Ruhrgebiet’, in H. Proff (ed.) *Neue Dimensionen der Mobilität: Technische und betriebswirtschaftliche Aspekte*. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 361–386. Available at: https://doi.org/10.1007/978-3-658-29746-6_31.

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# Citizen council(s) and dashboard(s) to discuss

https://vsp.berlin/sounding-board

**Staatliche Einnahmen:** welche die jeweiligen Maßnahmen pro Jahr, pro Jahr und Kopf sowie pro Jahr und erwachsene Person einbringen. Falls negativ, dann sind hiermit staatliche Ausgaben/Kosten gemeint.

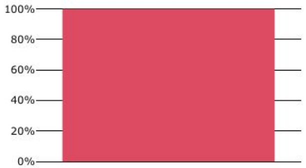
## TYPICAL SCENARIOS

2023 - Base | 2045 - Antriebswende | 2045 - autoarm | 2045 - Rufbusse statt Privatfahrzeuge

## RESULTS

**CO2**

100 %




**Fahrender Autoverkehr**

100 %


**Parkende Autos**

100 %


**Staatl. Einnahmen pro Jahr**

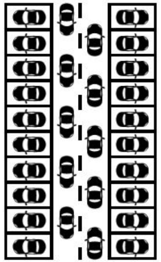
0 €

**Staatl. Einnahmen pro Kopf und Jahr**

0 €

**Staatl. Einn. pro Erw. und Jahr**

0 €



## EXPERIMENT CONDITIONS

**ÖPNV**: base | dekarbonisiert | stark

**Kiezblöcke**: base | ganze Stadt

**Fahrrad**: base | stark

**Parkraum**: base | Besucher_teuer_Anwohner_preiswert | Besucher_teuer_Anwohner_teuer

**fahrender Autoverkehr**: base | mautFossil | MautFuerAlle | zeroEmissionsZone | zeroEmissionsZonePlusMaut | autofrei

**DRT**: base | nurAussenbezirke | ganzeStadt

## DESCRIPTION

**ÖPNV: Öffentlicher Personennahverkehr: hierzu gehören S-Bahn, U-Bahn, Tram und Bus**

base: Stand heute

# Some results from citizen council

> 80% support of:

- **General goal** of non-fossil traffic.
- Going **beyond pure drive transition**.
- **Compensations to losers**.
- **++ of**: public transport, bicycle infra, car sharing, demand-responsive transit.
- Long-term **plannable goals**.
- Internalization of external costs ("Verursacherprinzip")...
  … but **no majority for any of the concrete push measures** (e.g. "toll", "parking fees", zero emissions zone).

Wide agreement on overall goals; wide agreement on (costly) "pull" measures; people want fewer cars but no agreement on "push" measures.

Kreuschner, M. *et al.* (2023) 'Dekarbonisierung des Verkehrssektors in Berlin: Bürger:innengutachten zu wissenschaftlich erstellten Szenarien', *Depositonce* [Preprint]. Available at: https://doi.org/10.14279/depositonce-18736.

# Didn't we know this?

Widespread saying in Germany: "With respect to decarbonization, we do not have a knowledge but an implementation deficit. Everybody (or: The experts) know(s) what needs to be done."

— no! This is not the issue. Rather have more than one path and cannot decide which one to implement (also between experts). Cannot (should not?) expect of politicians to move without a majority.

→ Headed towards pure drive transition, but with delayed implementation.

**What to do (in Germany)?**

- Concentrate on commercial actors. At least ⅓ of $CO_2$ in surface transport.
- High GER fuel tax will break away because move to electric. Revenue, implicit toll. →(?) Replace by some km-based charging. Be prepared, esp. as research.

# Conclusion

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# Conclusion

**Solutions** for carbon-free urban traffic **exist**.

**Less expensive** than one may expect.

Decarbonisation of **private traffic** in Berlin **stuck in discussion** if

- replace fossil by non-fossil cars (“**Antriebswende**”)

or

- combine with general change of transport system (“**Verkehrswende**”).

Recommend **focus on commercial traffic** (less controversial).

# Rural areas

# Starting point

In GER rural public transit cross-subsidized by school traffic.

Our simulations: School traffic with electric shuttles (and human drivers) only about 30% more expensive than current system (with buses). ~ 1600Eu/(Person x Jahr)

Remainder of day shuttle system at marginal cost.

*Much* more attractive than current rural public transit.

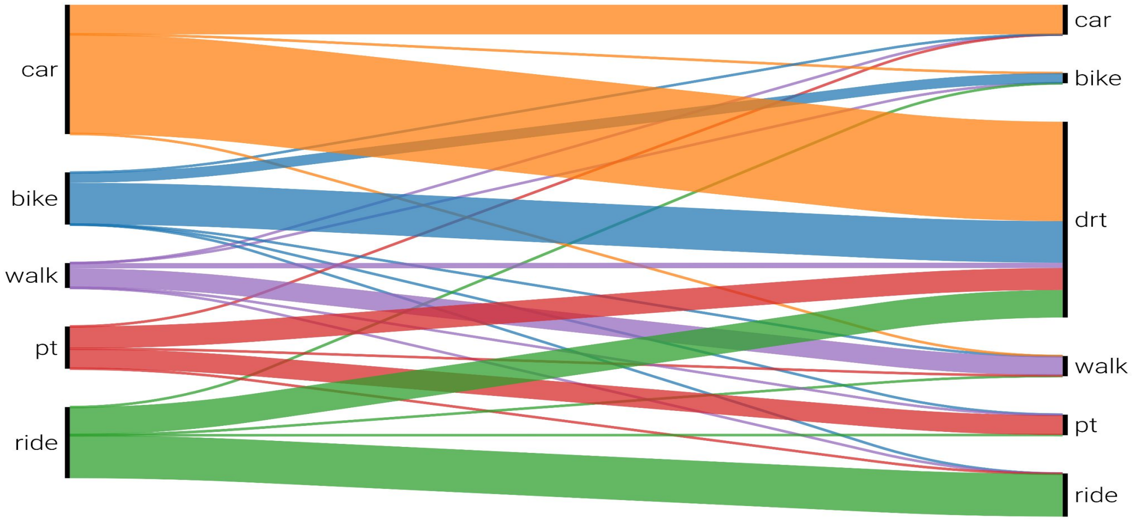
Lu, C. *et al.* (2022) 'Demand-Responsive Transport for Students in Rural Areas: A Case Study in Vulkaneifel, Germany'. Available at: https://doi.org/10.2139/ssrn.4181254.

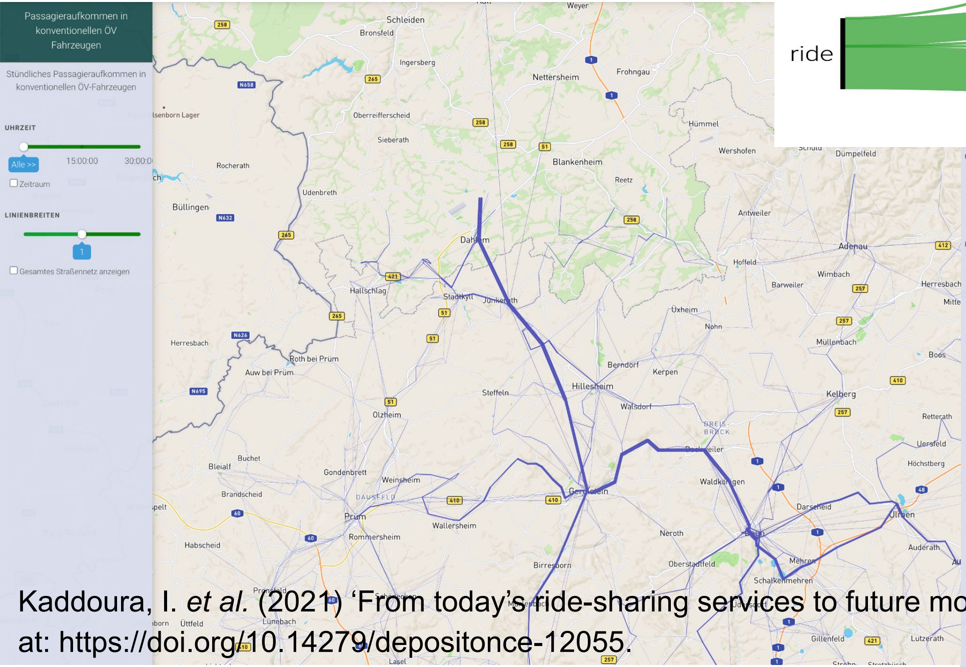
https://www.saechsische.de/teure-buskinder-3503771.html .

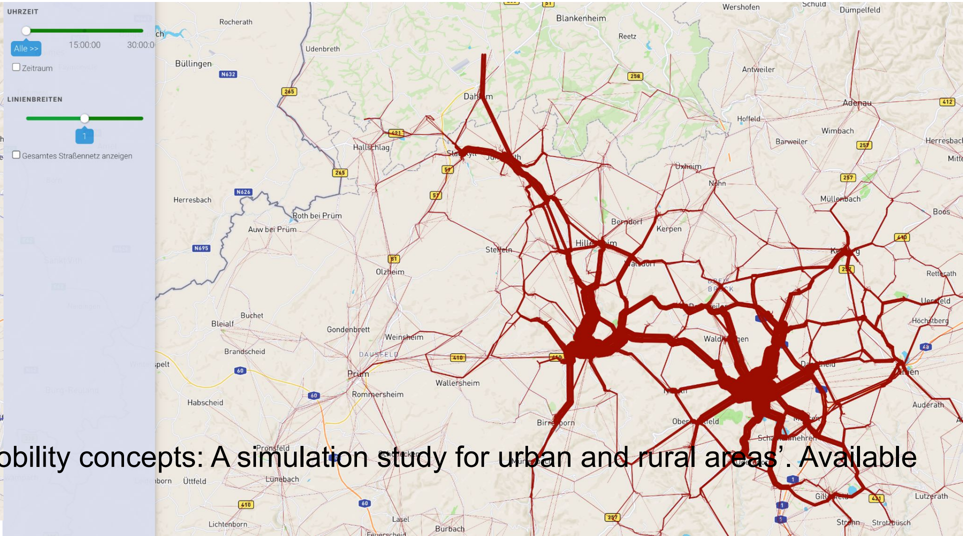
https://www.vulkaneifel.de/images/pdf/abtZ/Haushalt_2022.pdf section 2410 page 53: 6.736 Mio Eu. I think that there are 7000 pupils + 1500 "berufsbildende Schulen" (www.vulkaneifel.de/beitraege/abt6/SEP). If 50% of them walk, for the remaining 50% we end up with about 1700Eu/yr.

# Shuttles at current PT prices

- Strong mode choice reaction
- Much better “network”




Kaddoura, I. *et al.* (2021) ‘From today’s ride-sharing services to future mobility concepts: A simulation study for urban and rural areas’. Available at: https://doi.org/10.14279/depositonce-12055.