ETH zürich

Mobility as part of the Swiss Energy System
energy-systemic model and CO_2 reduction potentials

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Mobility and Energy

status-quo

Speed requires power

→ mechanical power lost to friction / aerodynamic drag

$\sim 15\ W$

→ ETH Hönggerberg

$\sim 150\ W$

→ Rapperswil-Jona

$\sim 18'500\ W$

→ Berne

$(\sim 1'120'000\ W)$

→ Bordeaux (FR)

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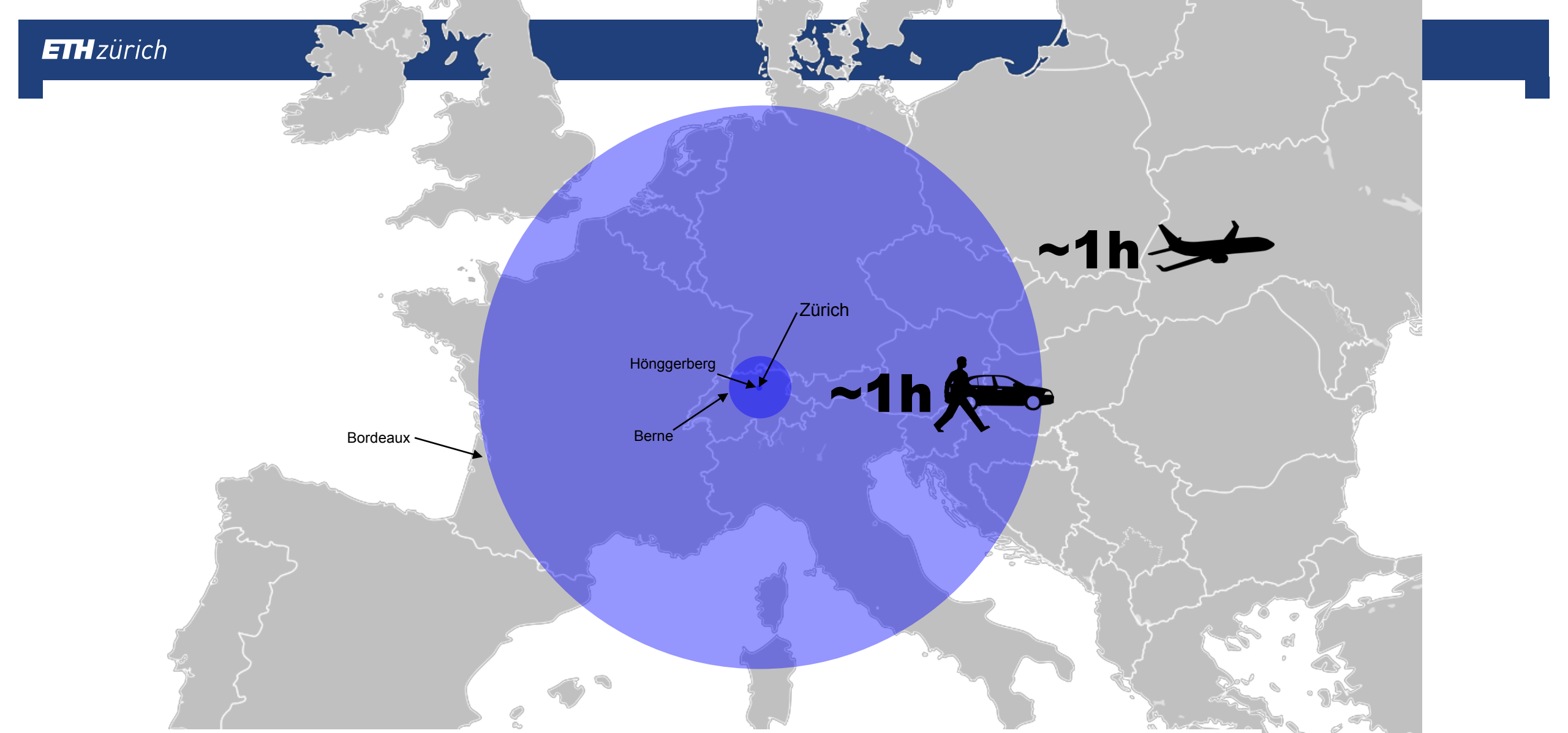
Rough estimates, assuming speed-independent drag and rolling resistance coefficients and disregarding certain practical constraints
For the plane → mechanical power, not thrust (!)



Velocity / power → Mobility

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Map source: Wikimedia Commons

Traveling requires energy

→ weight of converter, energy supply and total system

~6 km → ~ 0.02 kg *fat: 37 MJ/kg* → 1 → 0.02 kg/pax

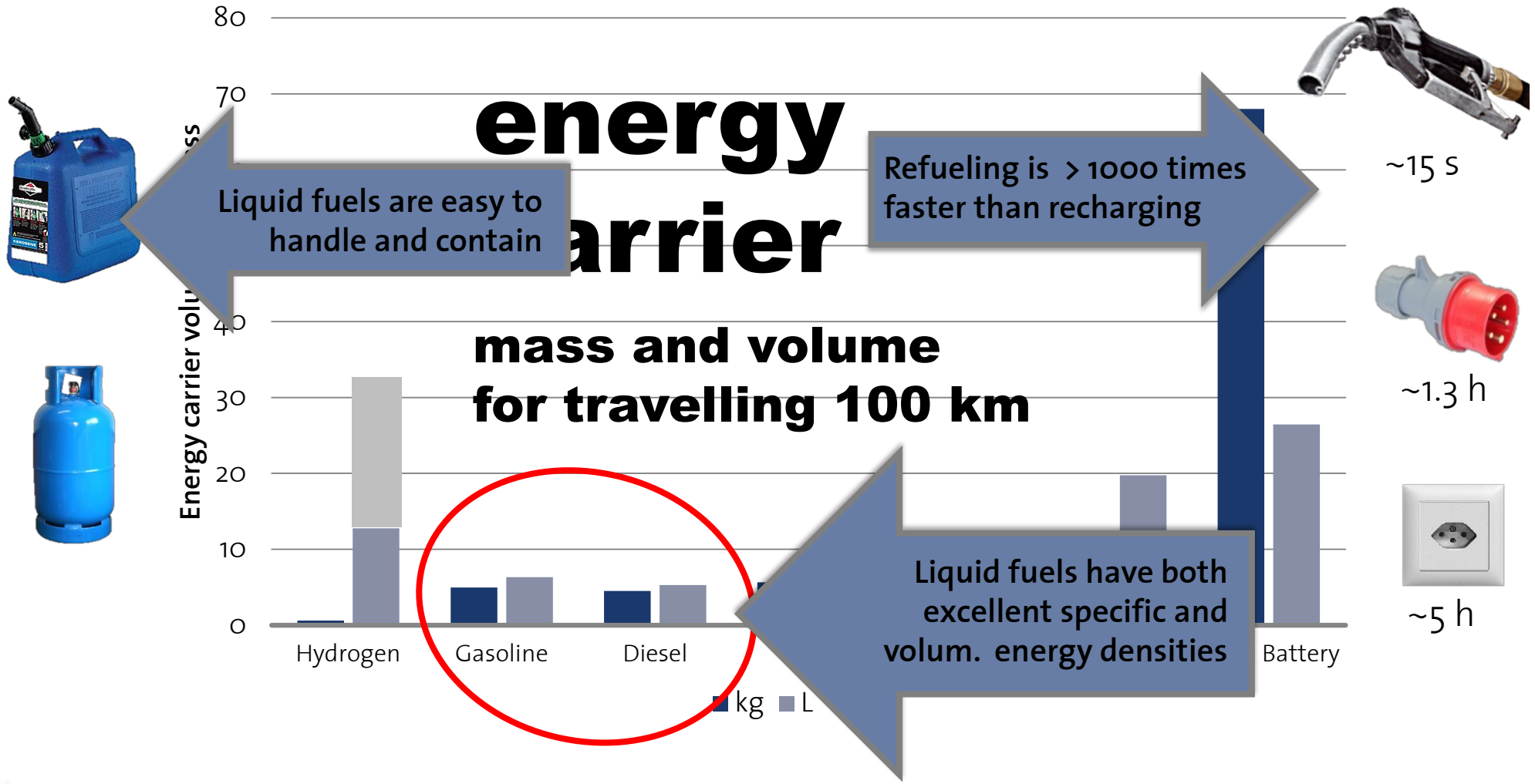
~60 km → ~ 0.1 kg *fat: 37 MJ/kg* → 1 → 0.1 kg/pax

~600 km → ~ 40 kg *gasoline: 44 MJ/kg* → 1.6 → 25 kg/pax

~6'000 km → ~ 15'000 kg *kerosene: 46 MJ/kg* → 150 → 100 kg/pax

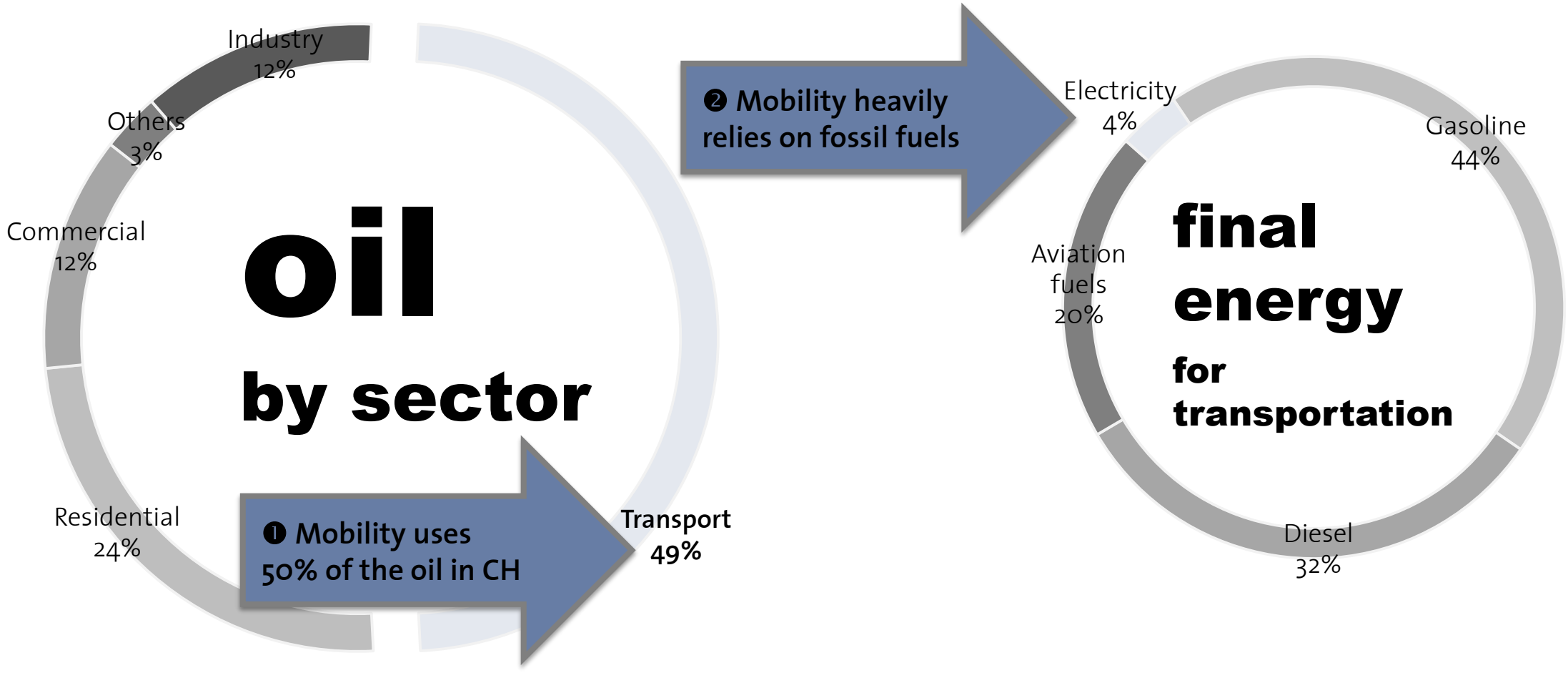
Liquid hydrocarbon fuels

→ a perfect match for mobile applications



Since liquid fuels are so practical, they are popular

→ the Swiss transportation sector is almost exclusively driven by fossil fuels



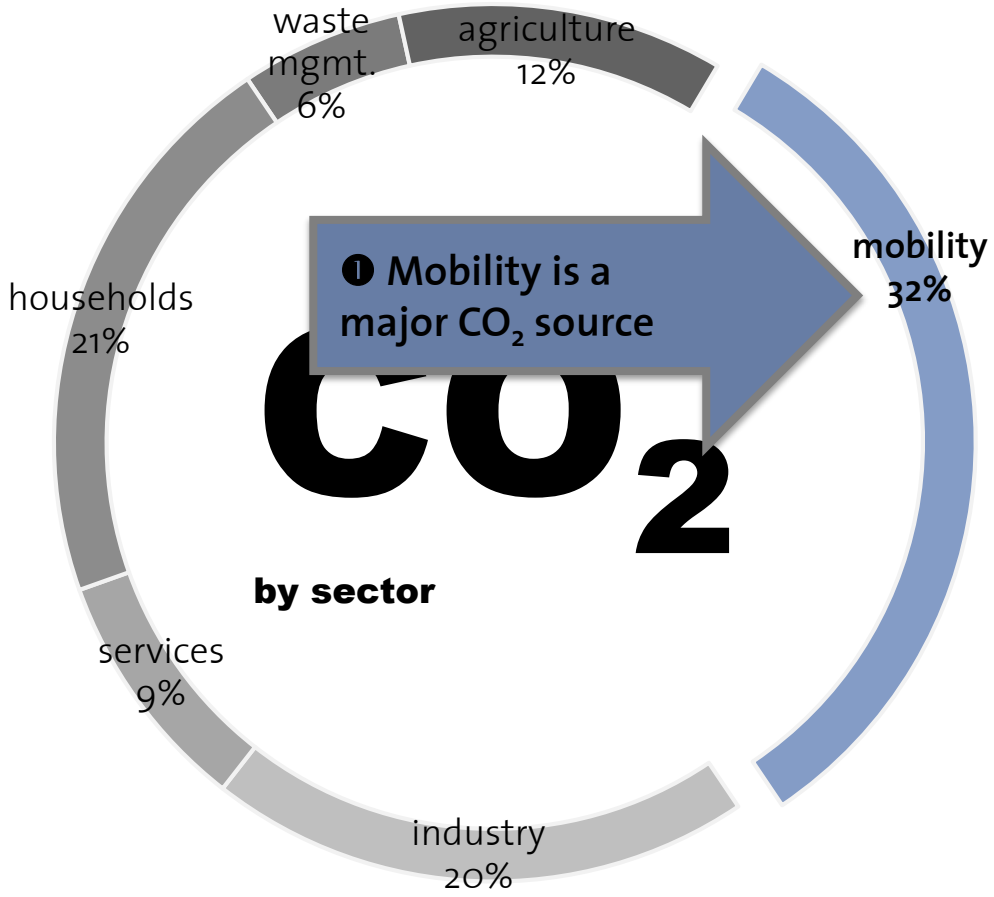
Sources: IEA, Energy Policies of IEA countries – Switzerland 2012: Review
Bundesamt für Statistik, Mobilität und Verkehr - Taschenstatistik 2012, Neuchâtel, 2012.

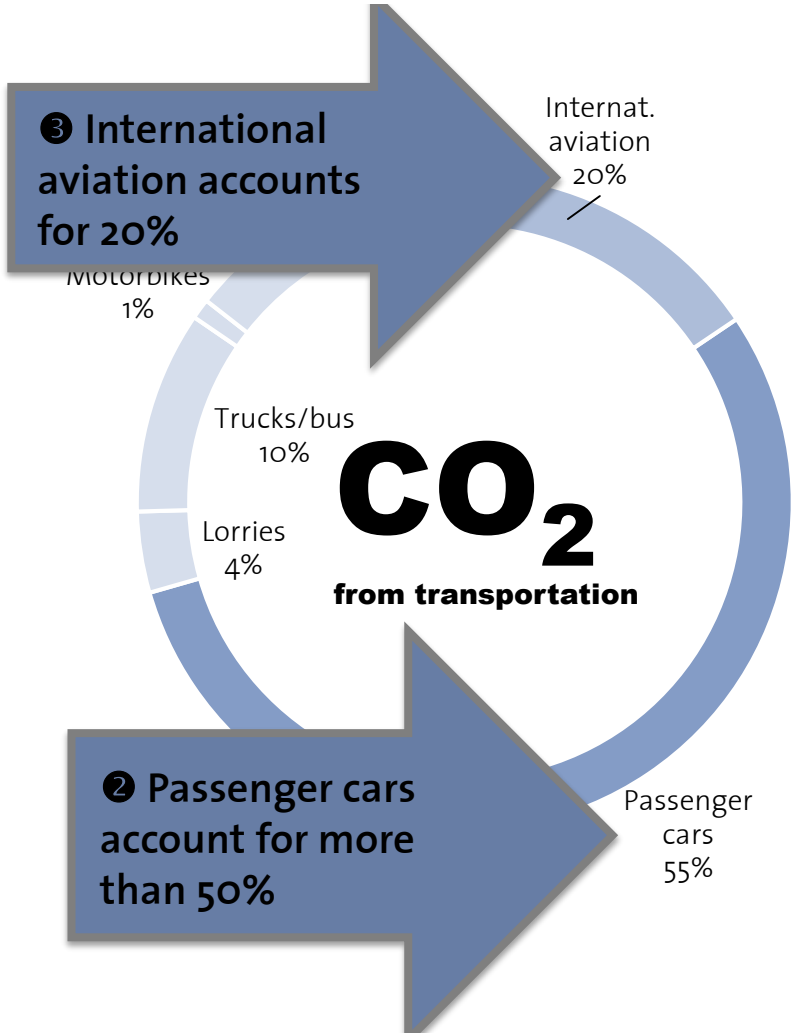
The issue:

fossil, liquid hydrocarbon fuels - a blessing and a curse

Transportation is not the only CO2 emitting sector

→ however, it is the single most important in Switzerland

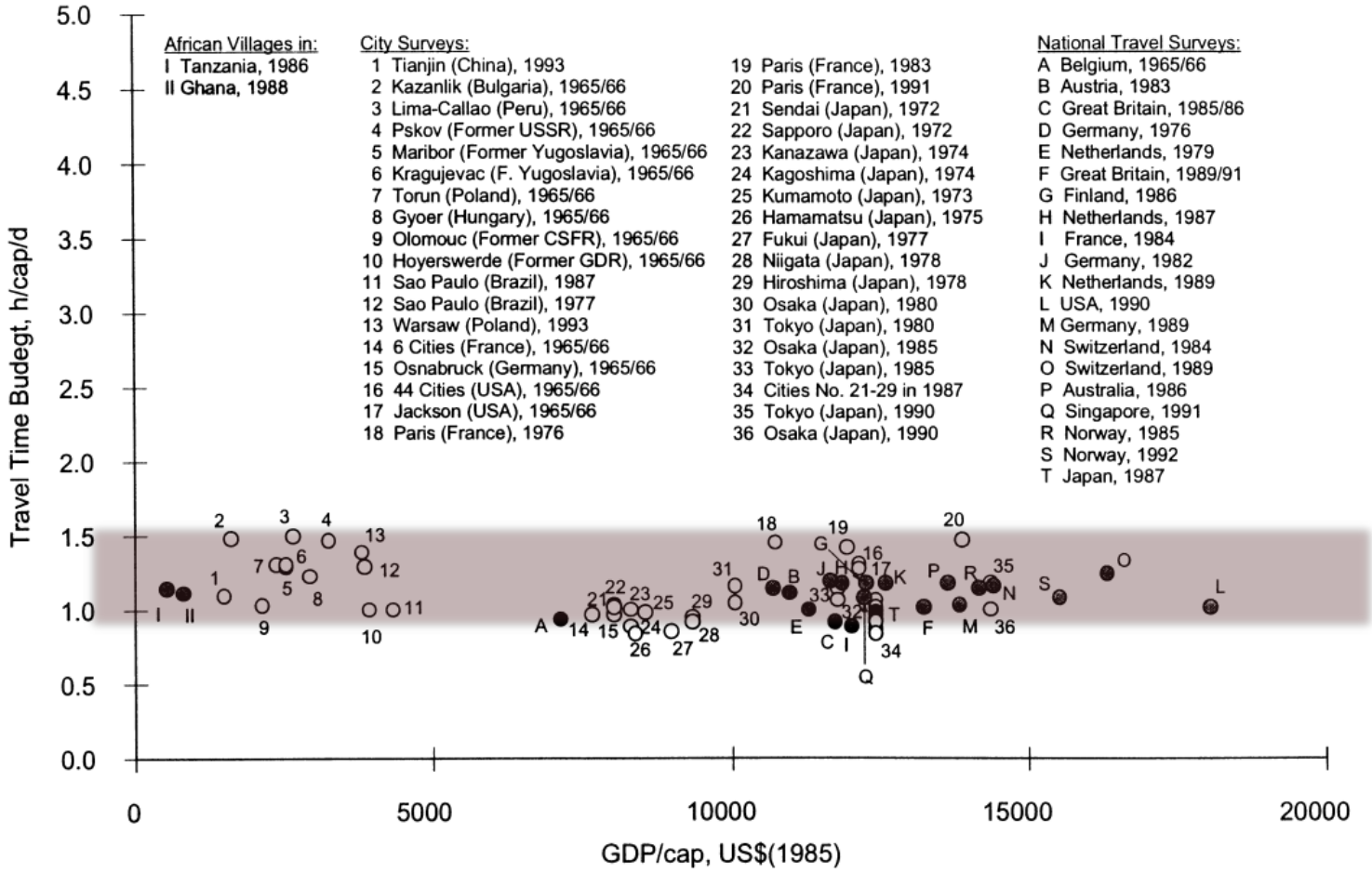




Source: Bundesamt für Statistik, Mobilität und Verkehr - Taschenstatistik 2012, Neuchâtel, 2012.

Mobility is more than mere luxury

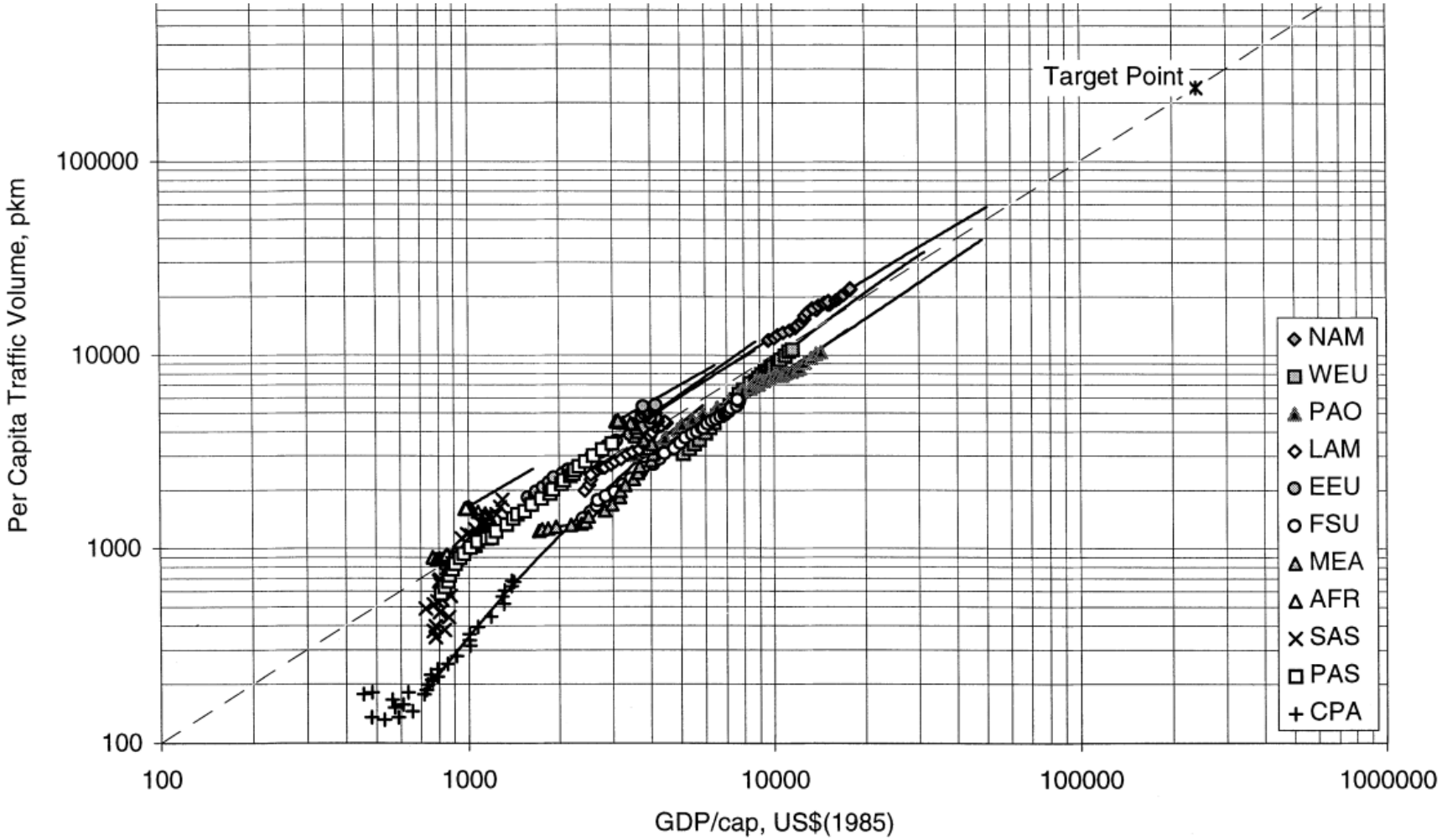
→ independently of income, people are mobile ~1h per day, everywhere



Source: A. Schafer, D.G. Victor, The future mobility of the world population, Transp. Res. Part A Policy Pract. 34 (2000) 171–205.

Speed on the other hand is a commodity

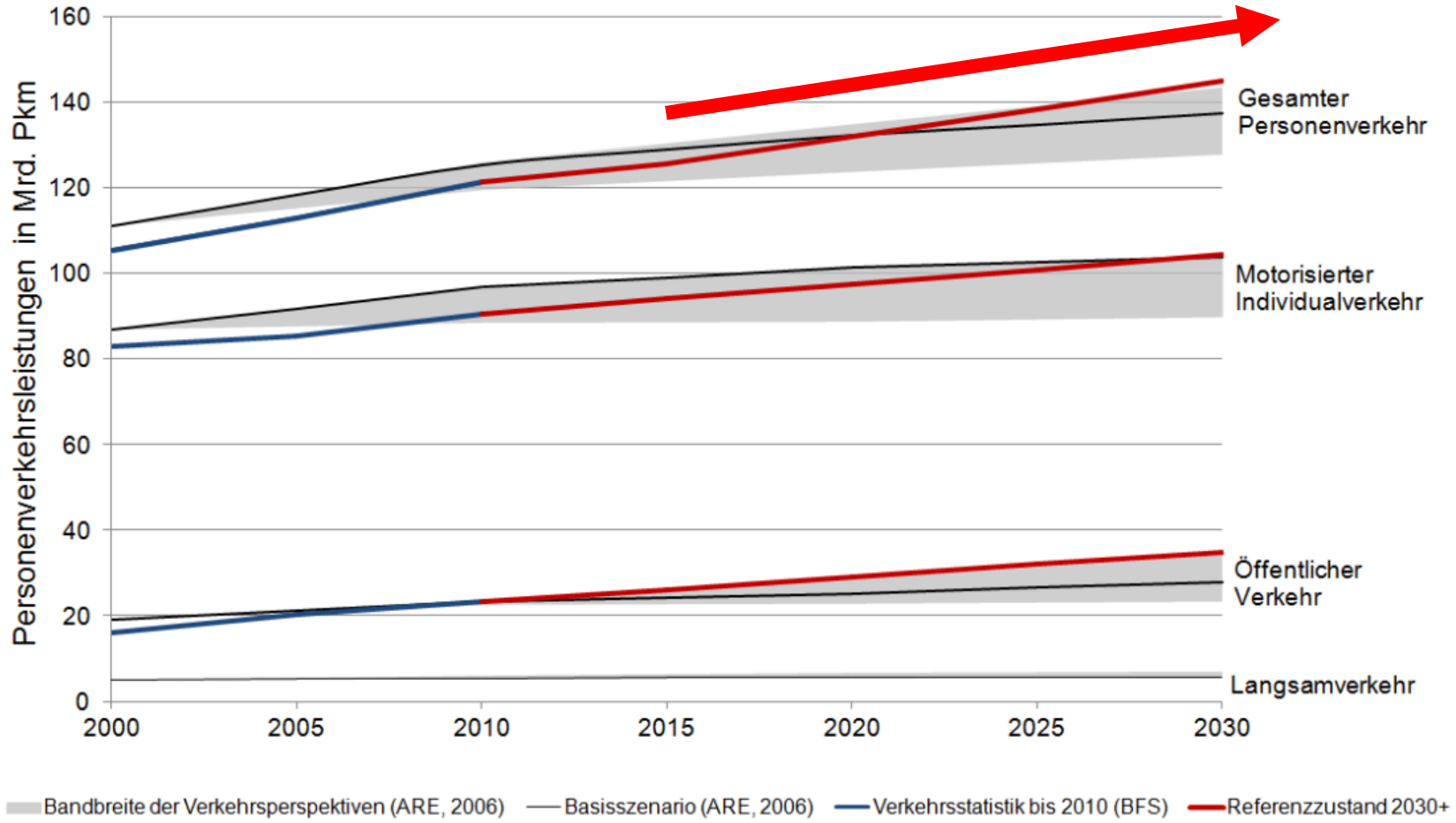
→ the demand for transportation increases with wealth



Source: A. Schafer, D.G. Victor, The future mobility of the world population, Transp. Res. Part A Policy Pract. 34 (2000) 171–205.

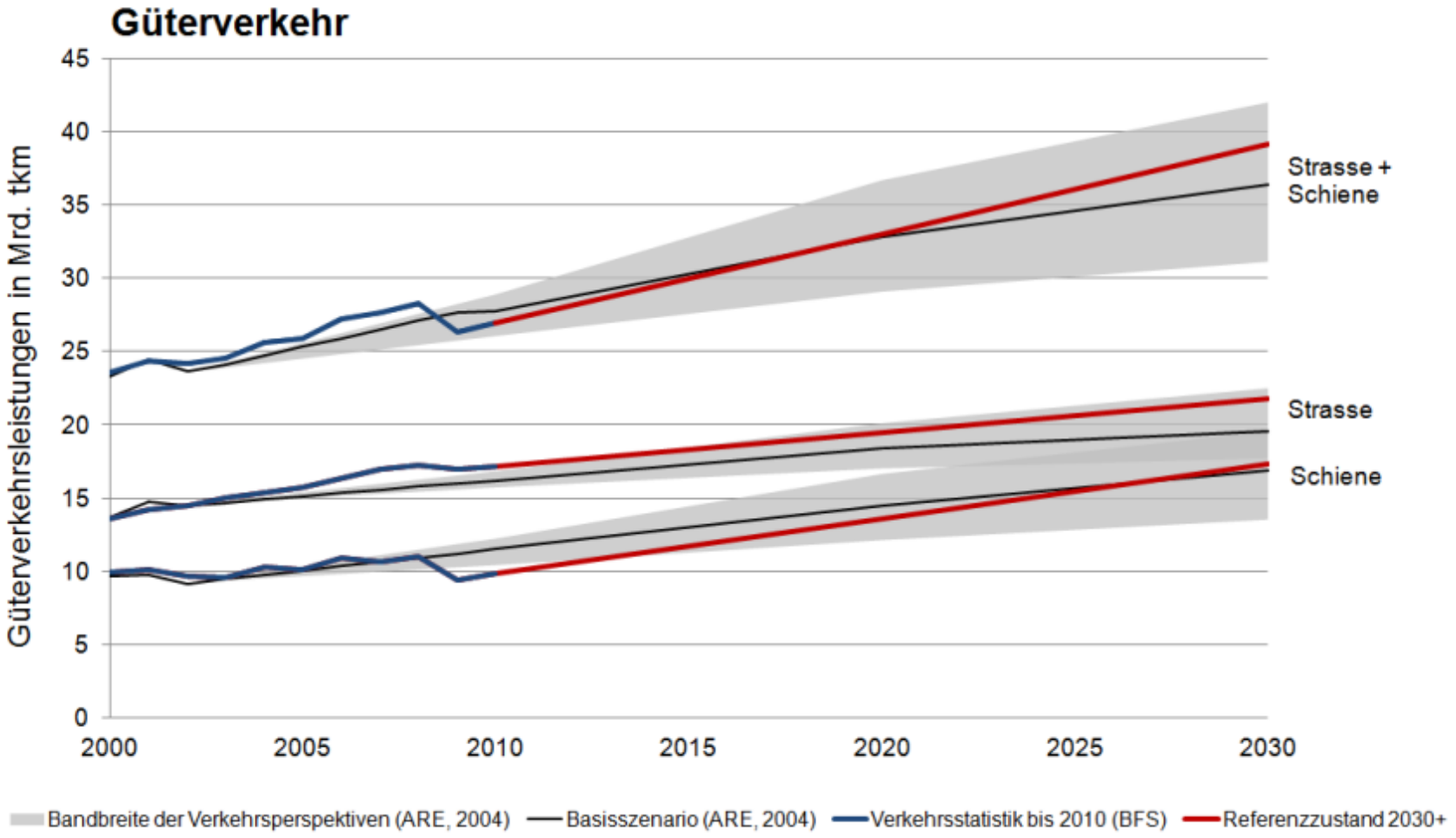
Tendency of the demand → increasing

→ continuous increase in private transportation



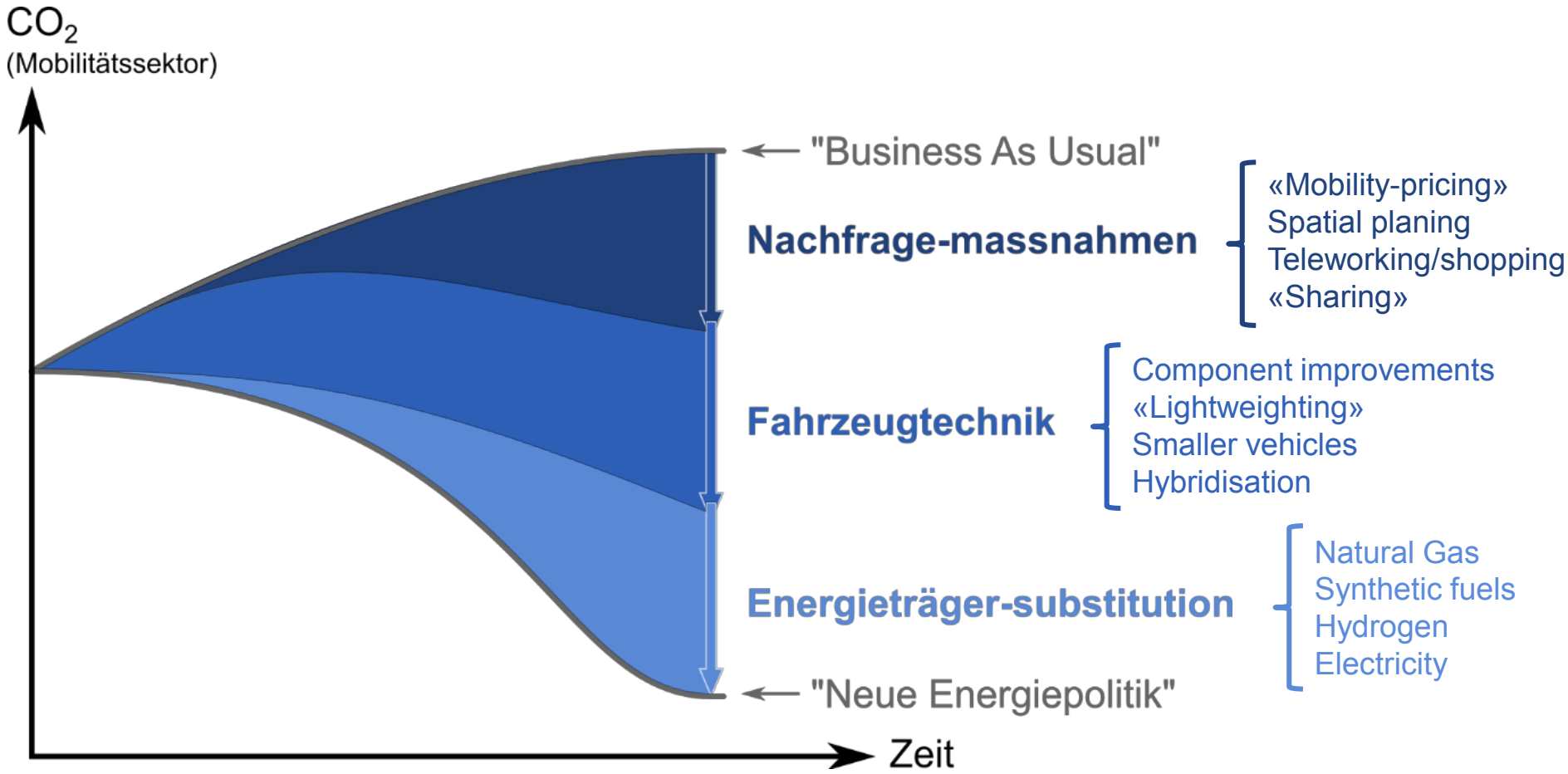
Tendency of the demand → increasing

→ almost double of transportation performance w.r.t. 2000



Perspectives & Countermeasures

→ Increase in CO_2 Emissions / demand- and technology measures



Describing mobility

An energy-systemic model of the Swiss transportation sector

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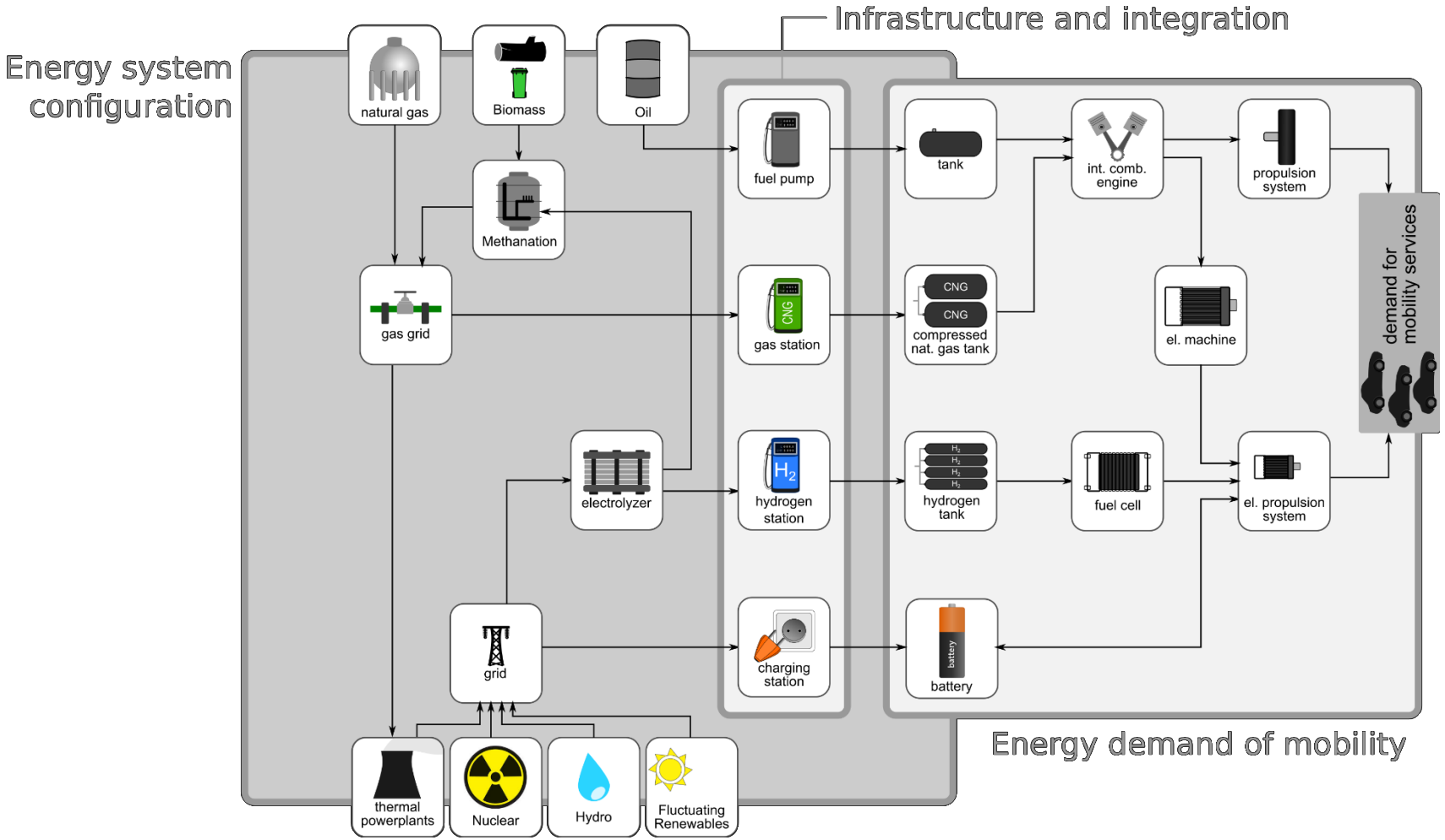
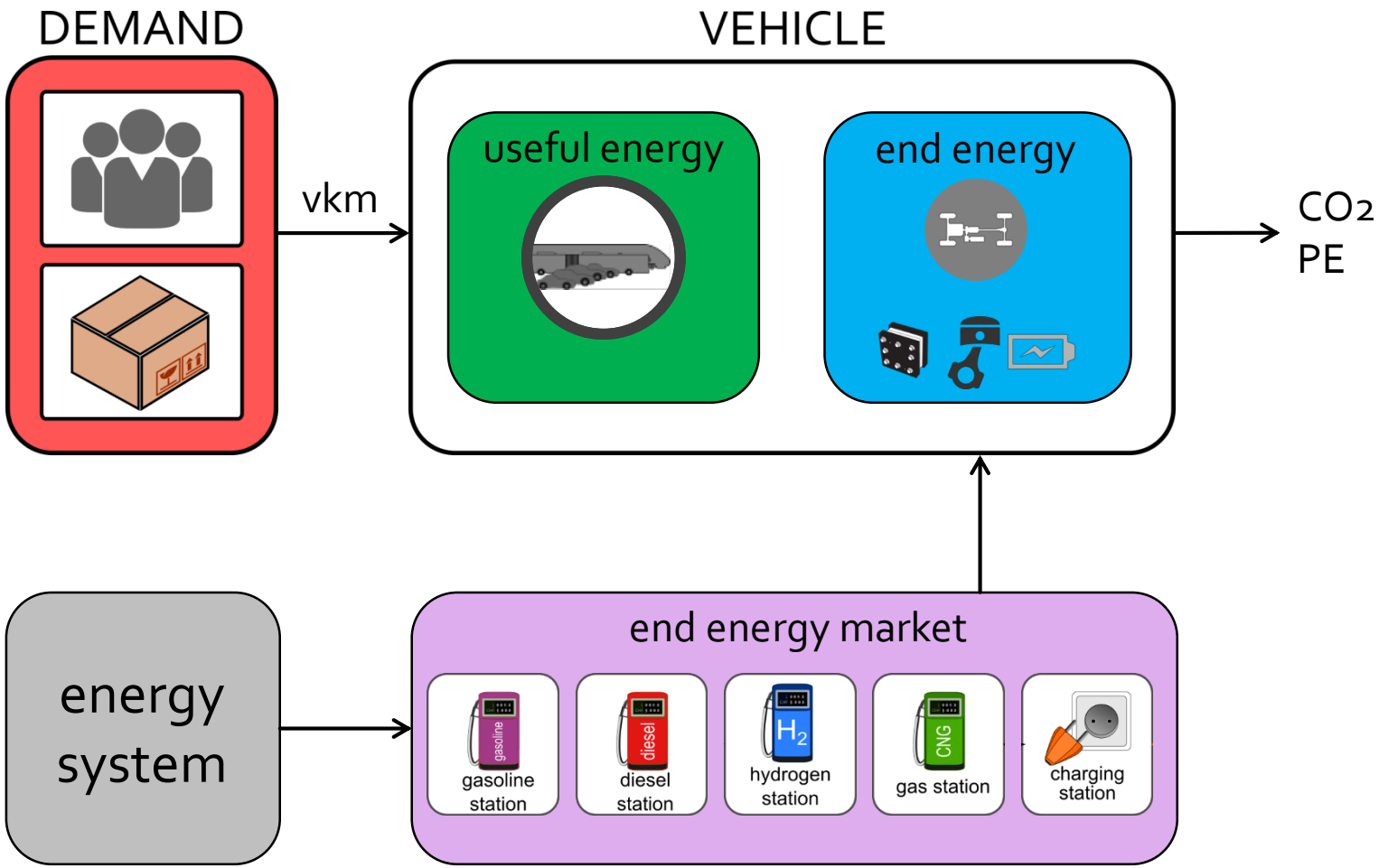
linking the mobility demand, vehicle technology and the energy system



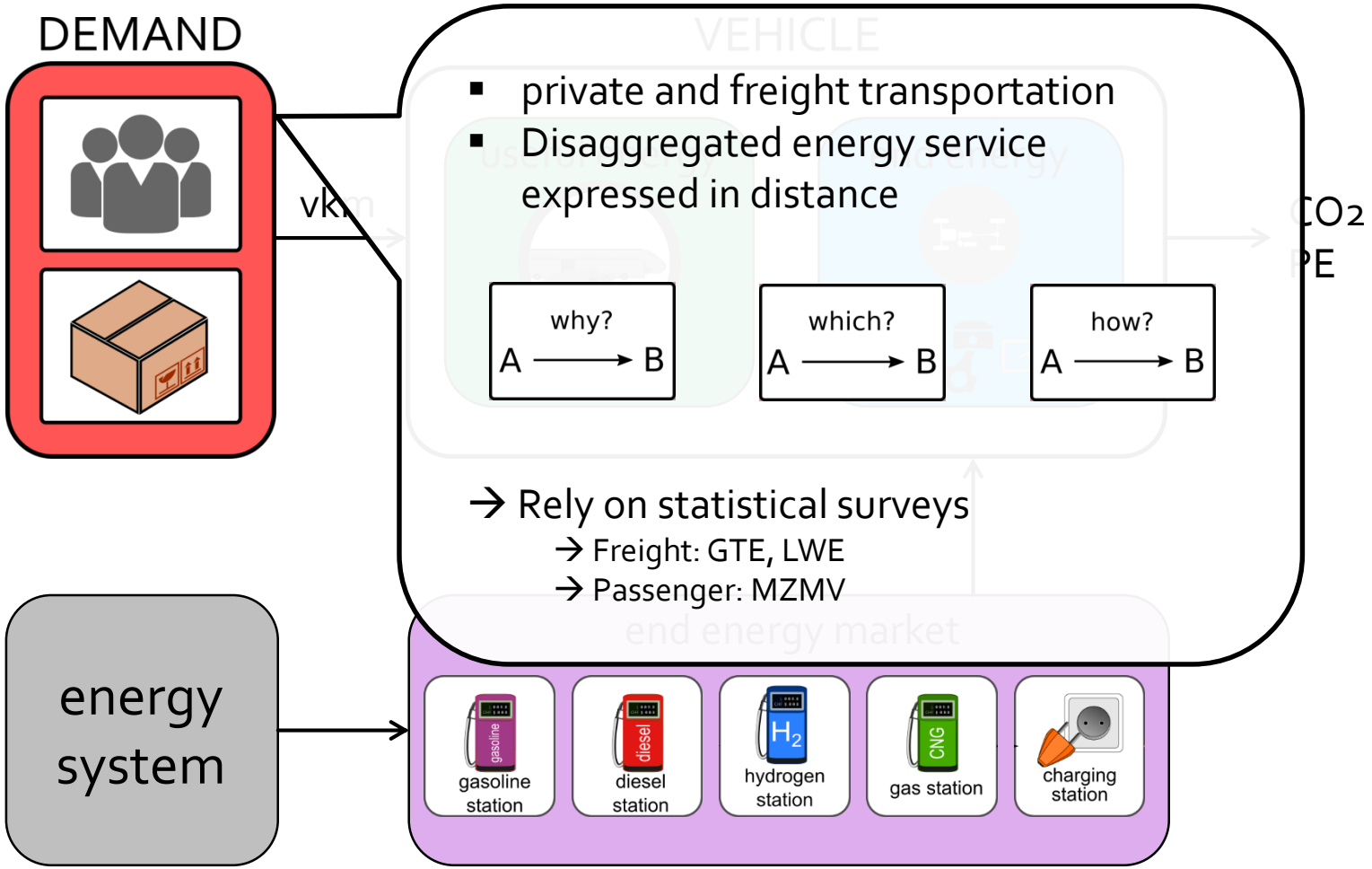
Energy-systemic model of the mobility sector (ESMOBIL)

linking the mobility demand, vehicle technology and the energy system



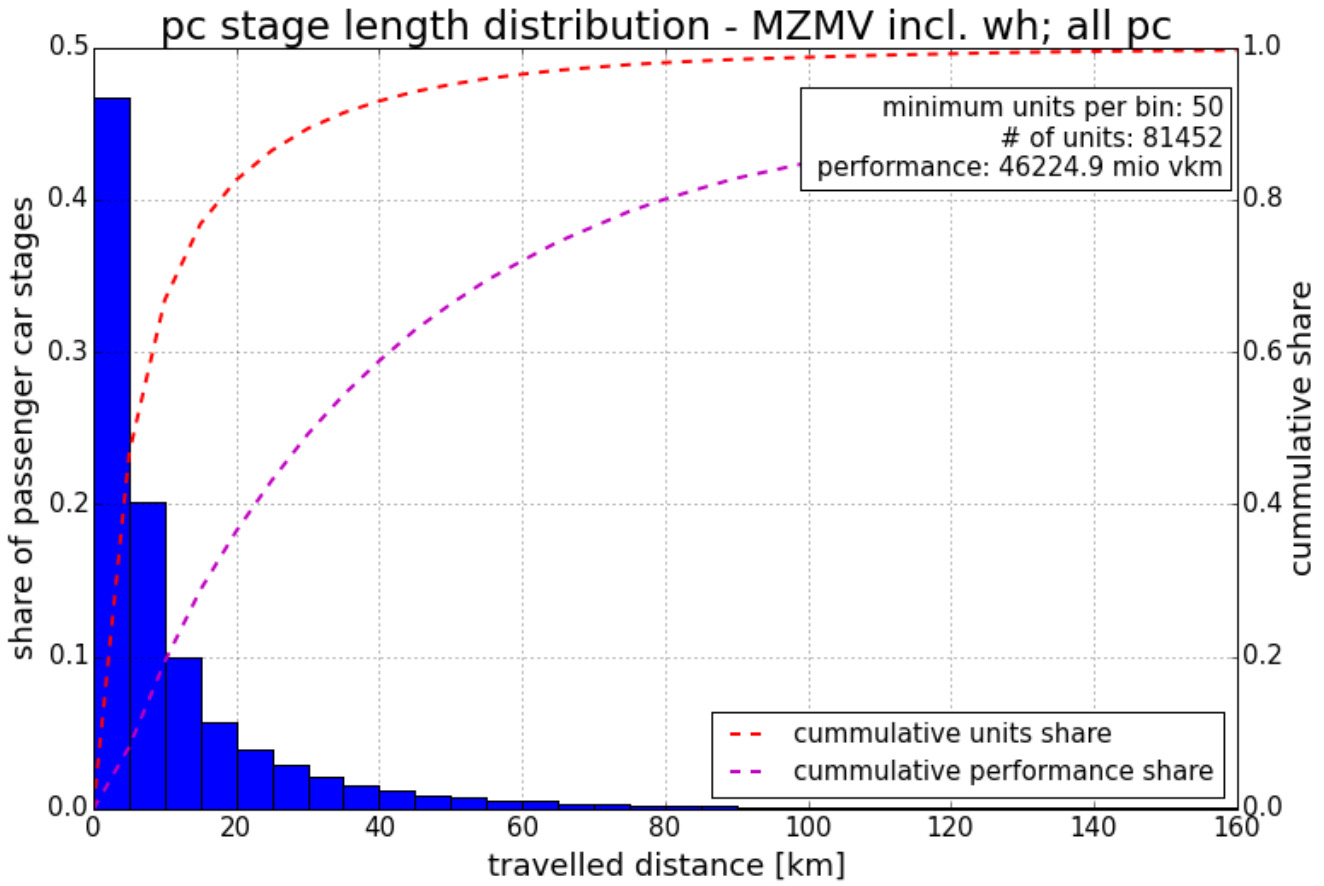
Energy-systemic model of the mobility sector (ESMOBIL)

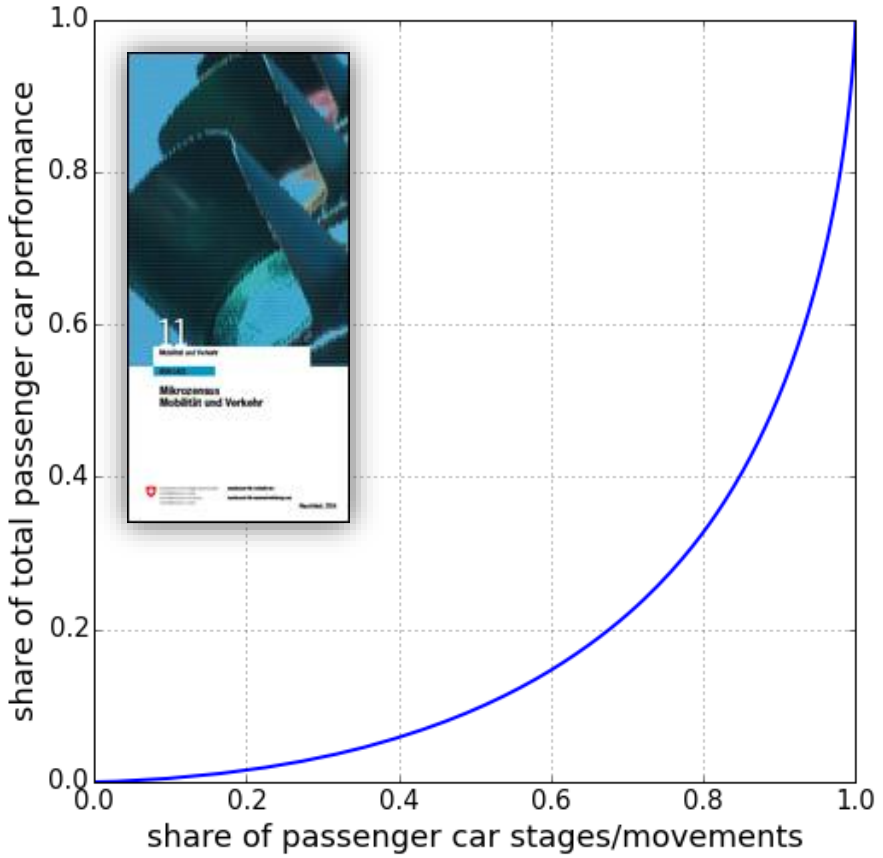
focus on mobility demand



Statistical data

→ Microcensus Mobility and Transportation of «BFS» for private tranportation

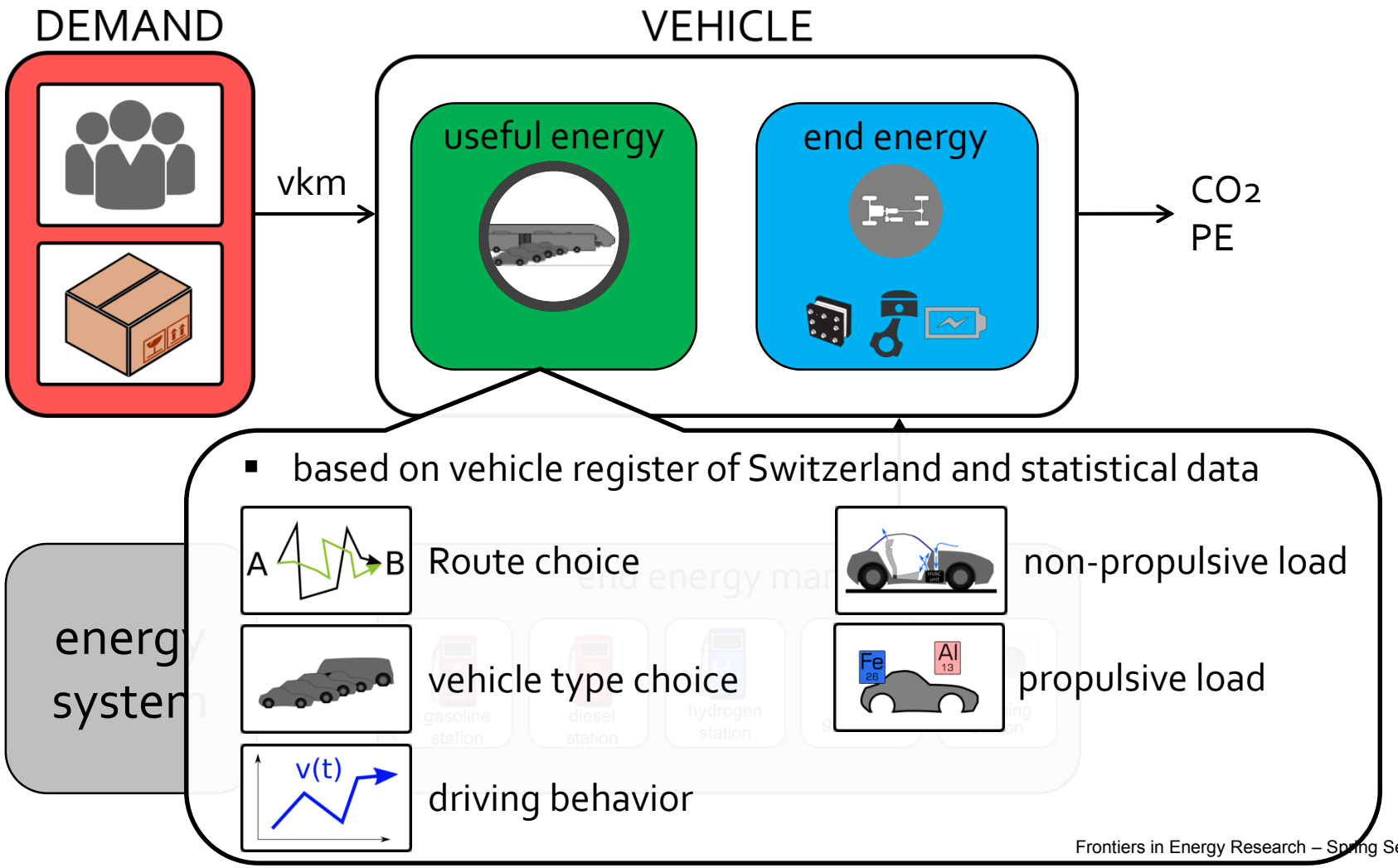




Source: «Mikrozensus Mobilität und Verkehr 2010», own calculations

Energy-systemic model of the mobility sector (ESMOBIL-RED)

translate “vkm” to real-world energy demand; propulsive energy demand



ESMOBIL-RED project

→ real-world energy demand modelling of different vehicles

- Core issue: difference in energy demand between test rig and real-world
  - Unrepresentative testing procedure (driving cycle / NEDC)
  - Additional Non-propulsive load
  - Effective load of the vehicle

- ETH Zurich, EMPA, Audi and Swisscom
- Approach:
  - 4 different powertrain technologies

    → Electric car (VW Golf E), Plug-in Hybrid (Audi A3 e-Tron), CNG (Audi A3 g-Tron), fuel cell (Hyundai iX35)
  - Test bench measurements
  - 2 years of field usage (car-sharing)
  - Component modelling based on extension of Willans-line approach
  - Heating, Ventilation and Air-conditioning modelling

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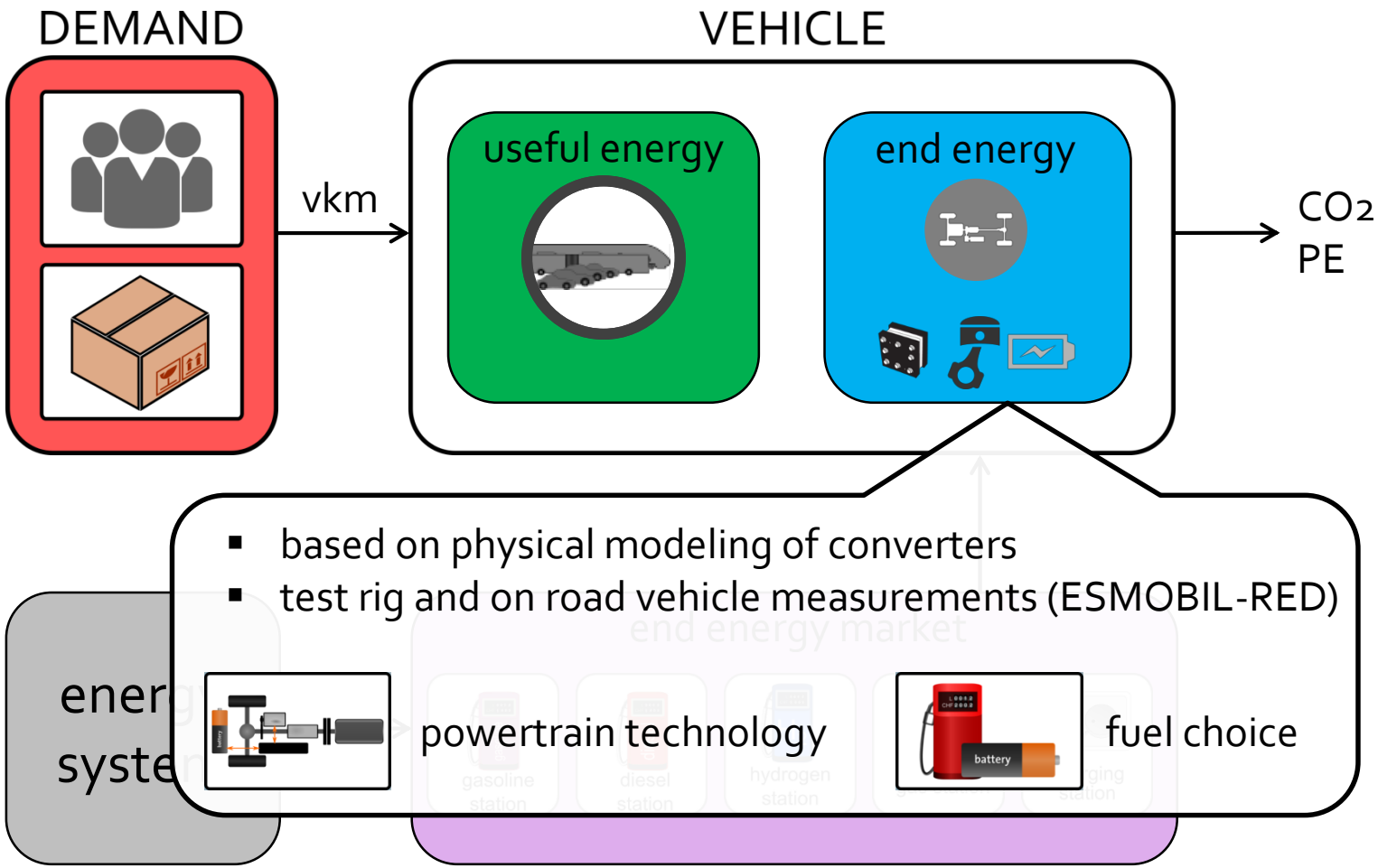
Source: MOFIS, ASTRA. Own calculations

Energy-systemic model of the mobility sector (ESMOBIL-RED)

translate “vkm” to real-world energy demand; powertrain technology and energy carriers



EXAMPLE: Willans-line

→ relation between input and output power

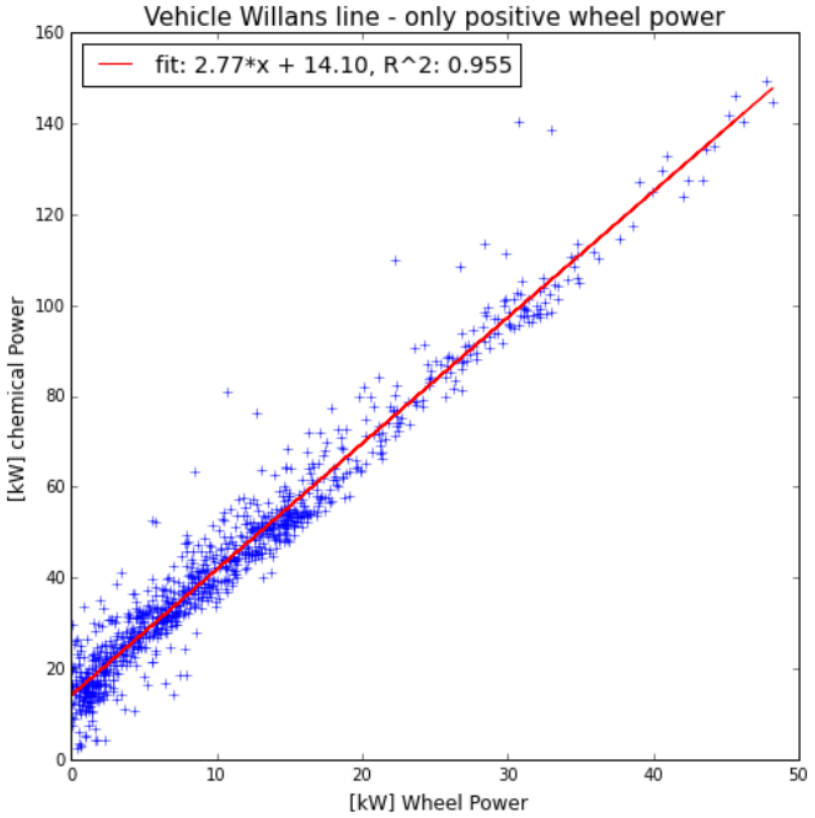
- Test rig measurement (EMPA):
  - Skoda Octavia C 1.8 4x4
  - WLTC Measurement
  - Willans line of vehicle (not components)

→ Linear relationship

→ scaleable

→ applicable to any kind of converter

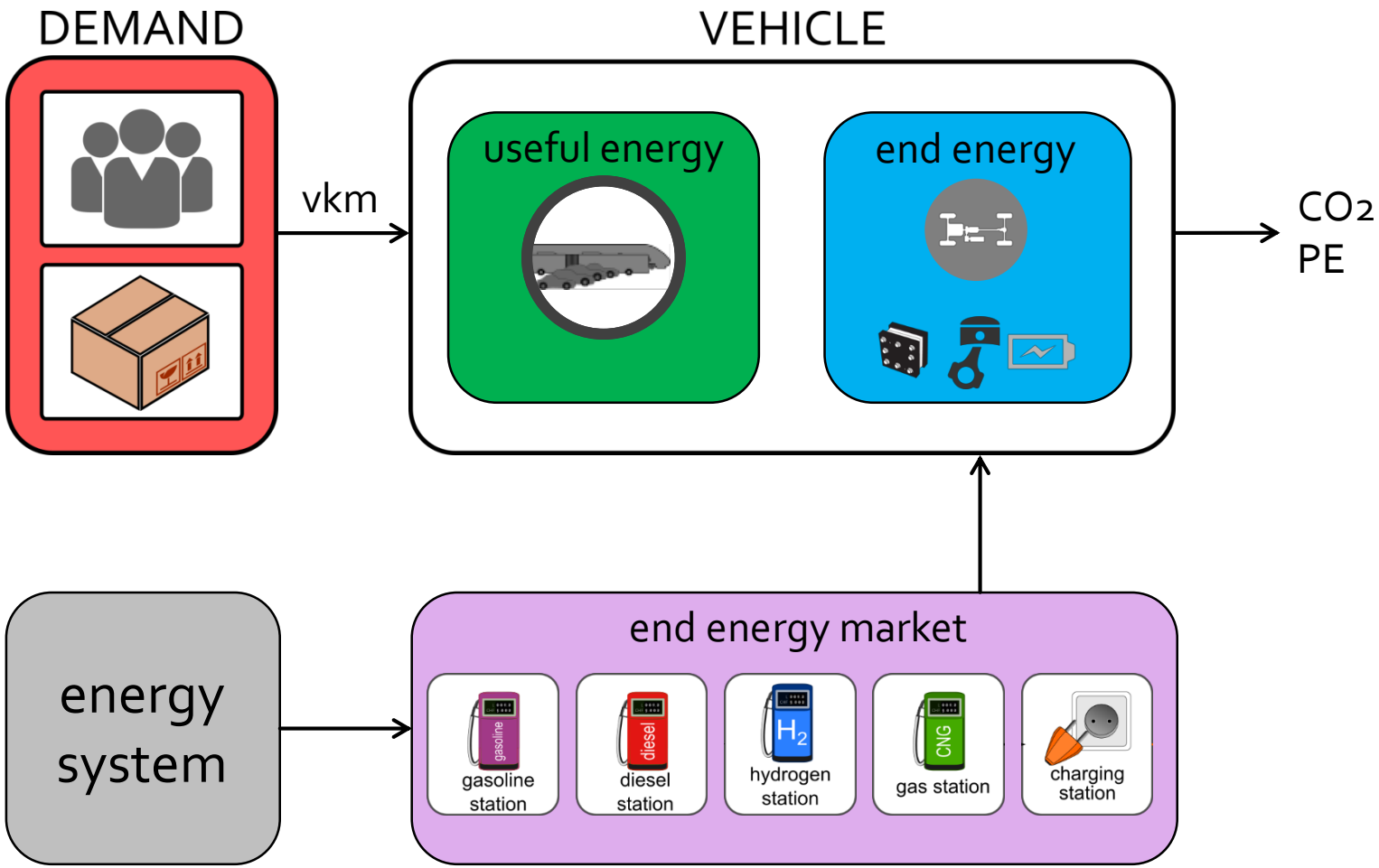
Vehicle: $P_{in} - P_{out}$



Source: EMPA, own calculations

Mobility and the Energy System

What can we do with the energy-systemic description of the mobility sector?



Example application:

What are the CO_2 reduction potentials?

Influencing demand

Social intervention – Reducing the «km»

Path 1: «sufficiency»

→ *Individual level: abstain from mobility*

Directly: incentivize less / sanction mobility

→ Sufficiency, mobility pricing

Indirectly: reduce the need

→ teleworking, urban planning

Path 2: «mode choice»

→ *System level: chose different modes*

Load factor: more people/freight per vehicle

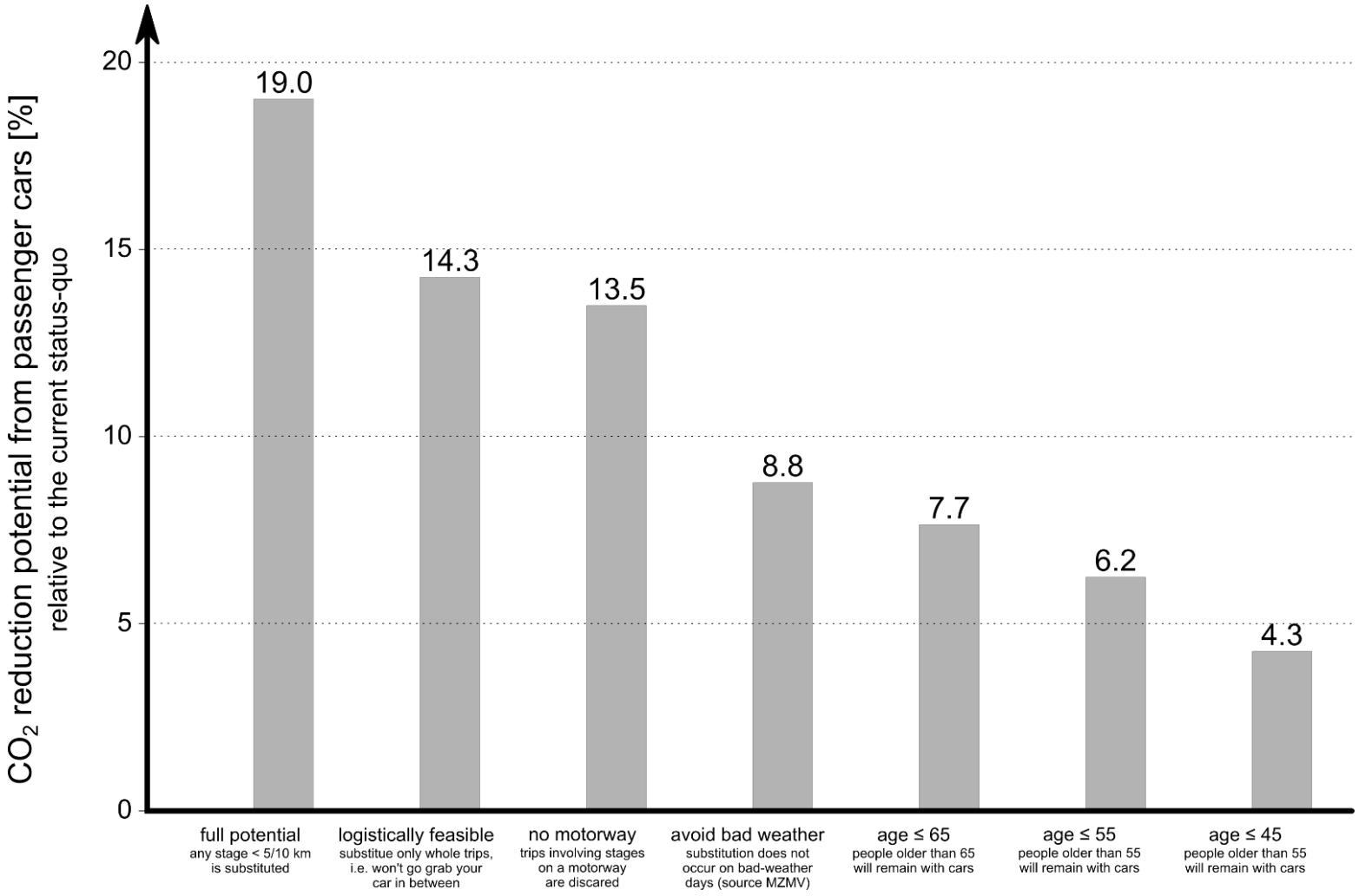
→ Car sharing, multi-modality, autonomous driving

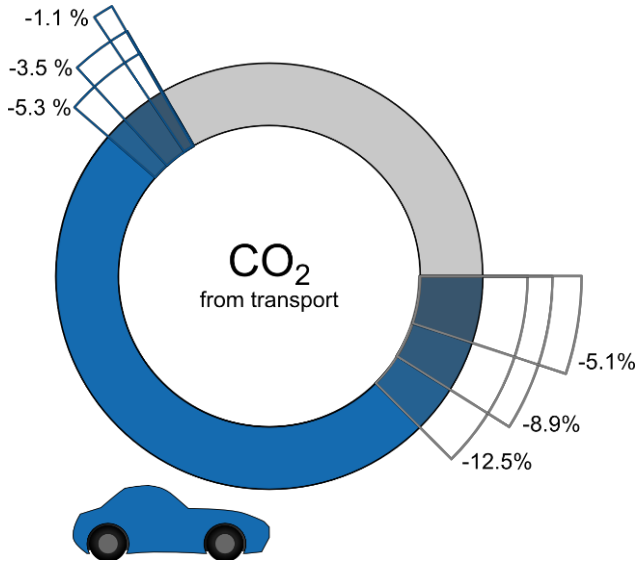
Efficiency: push towards efficient modes

→ Urban planning, incentives, rental bikes

EXAMPLE: promoting non-motorized mobility

Car trips are substituted by bicycles trips → but there are impediments

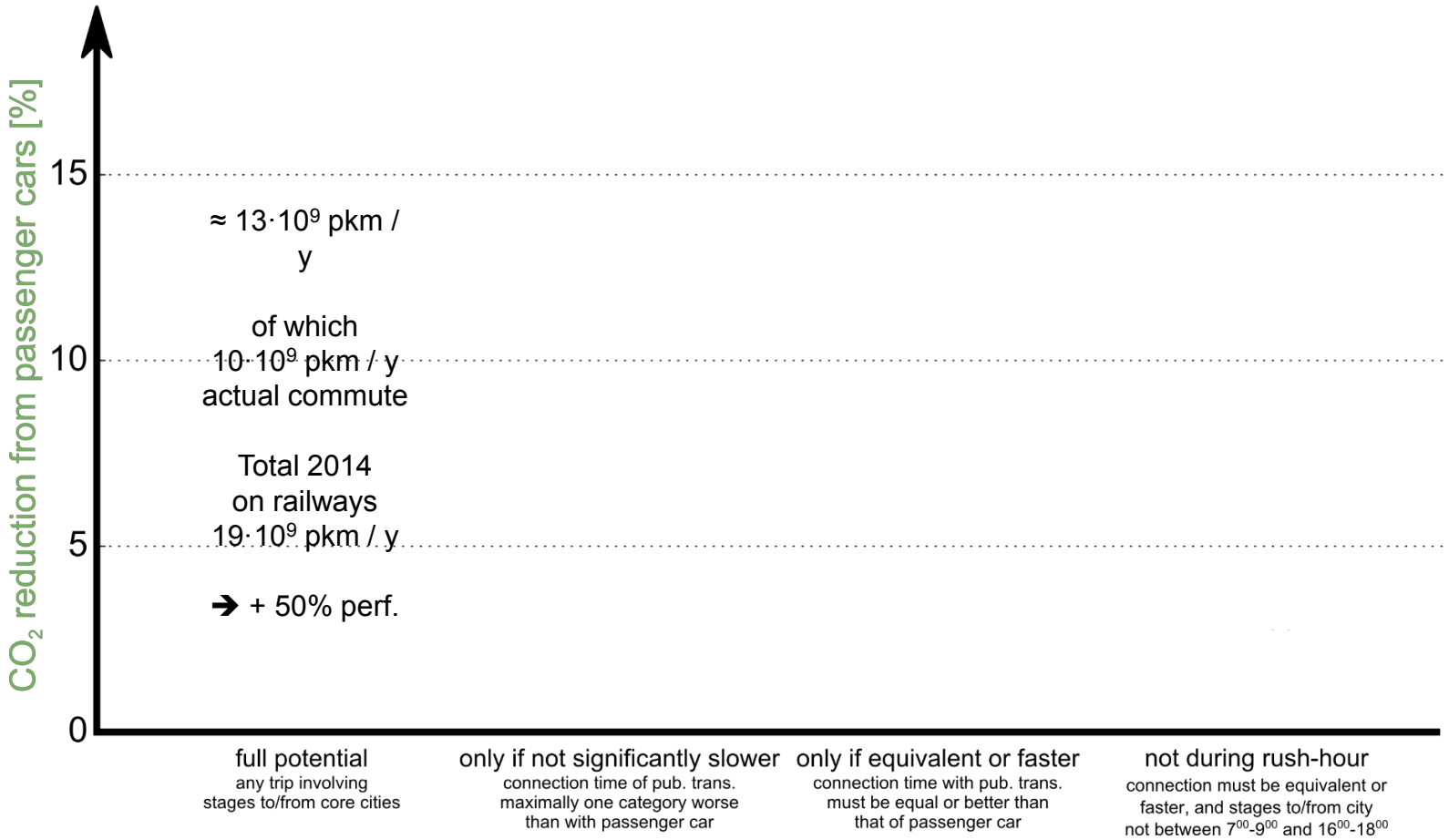


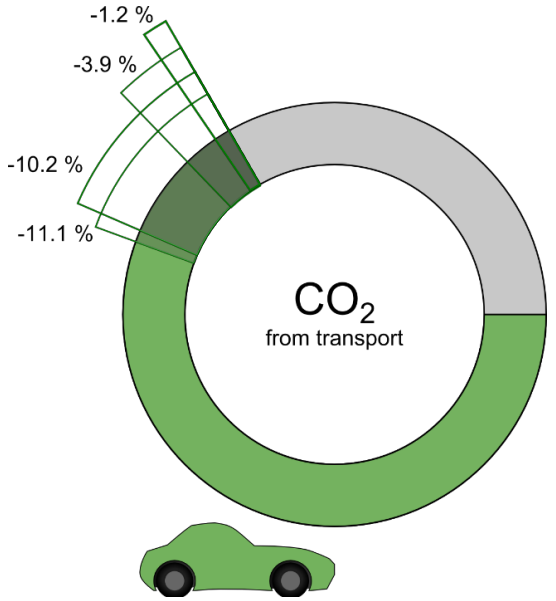


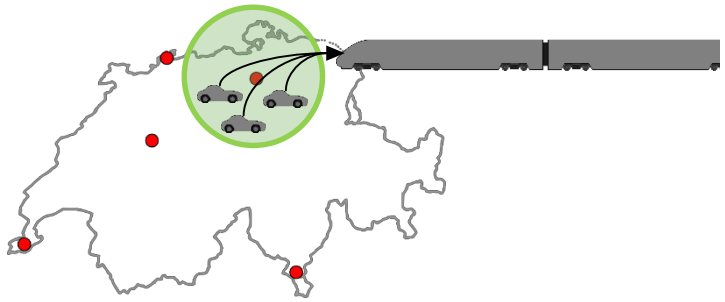
10 km

5 km

EXAMPLE: Elimination of commuting by passenger car







Modify vehicles

Technological intervention – Reducing the demanded energy

Path 1: «efficiency»

Improve existing technologies – same operation principles

→ aerodynamics, tribology, new materials, hybridization

Path 2: «carrier substitution»

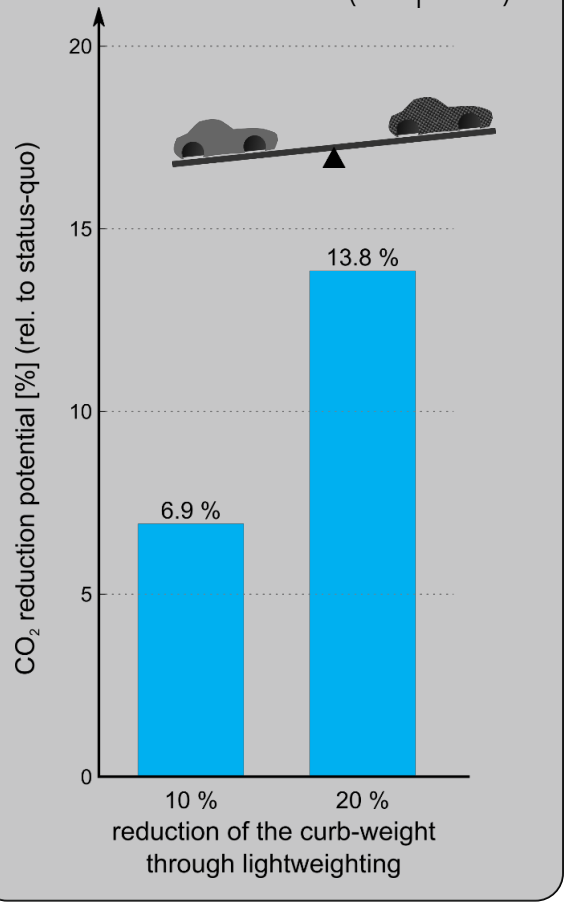
Replace fossil fuels by renewable energy carrier

→ electrification via batteries or fuel-cells

EXAMPLE: light weighting of passenger cars

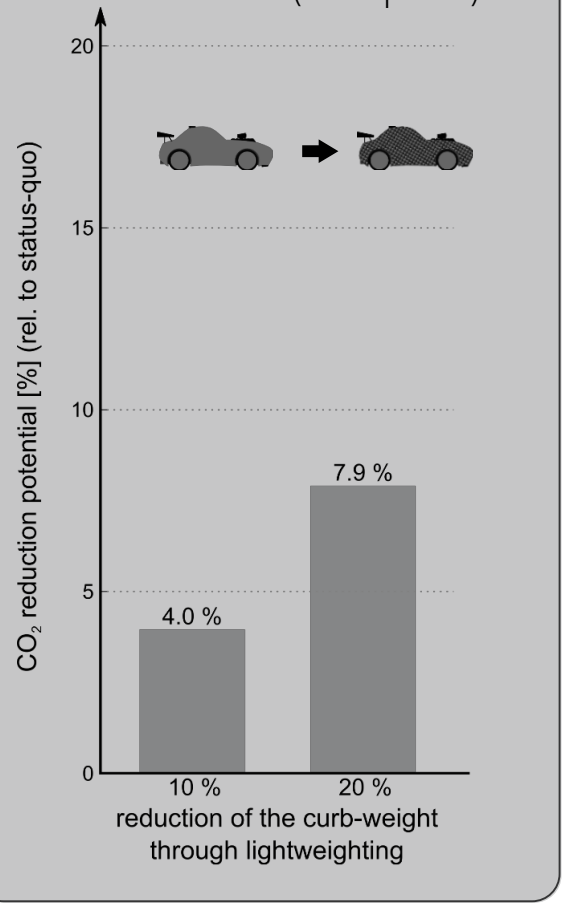
«Classical light weighting»

reduced curb-weight
but same acceleration (less power)



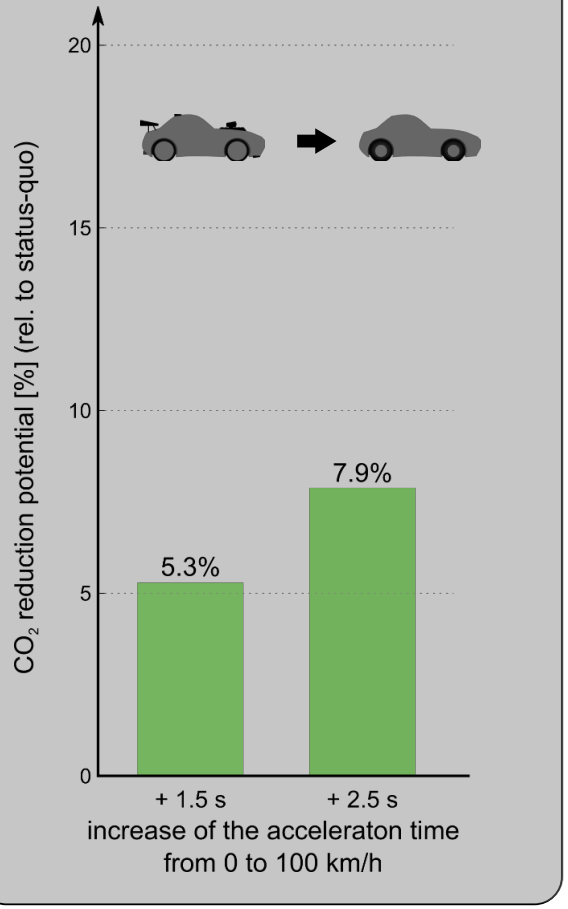
«Sporty light weighting»

reduced curb-weight
more acceleration (same power)



Sufficiency in power

same curb-weight
less acceleration (less power)



Path 1: «efficiency»

Improve existing technologies – same operation principles

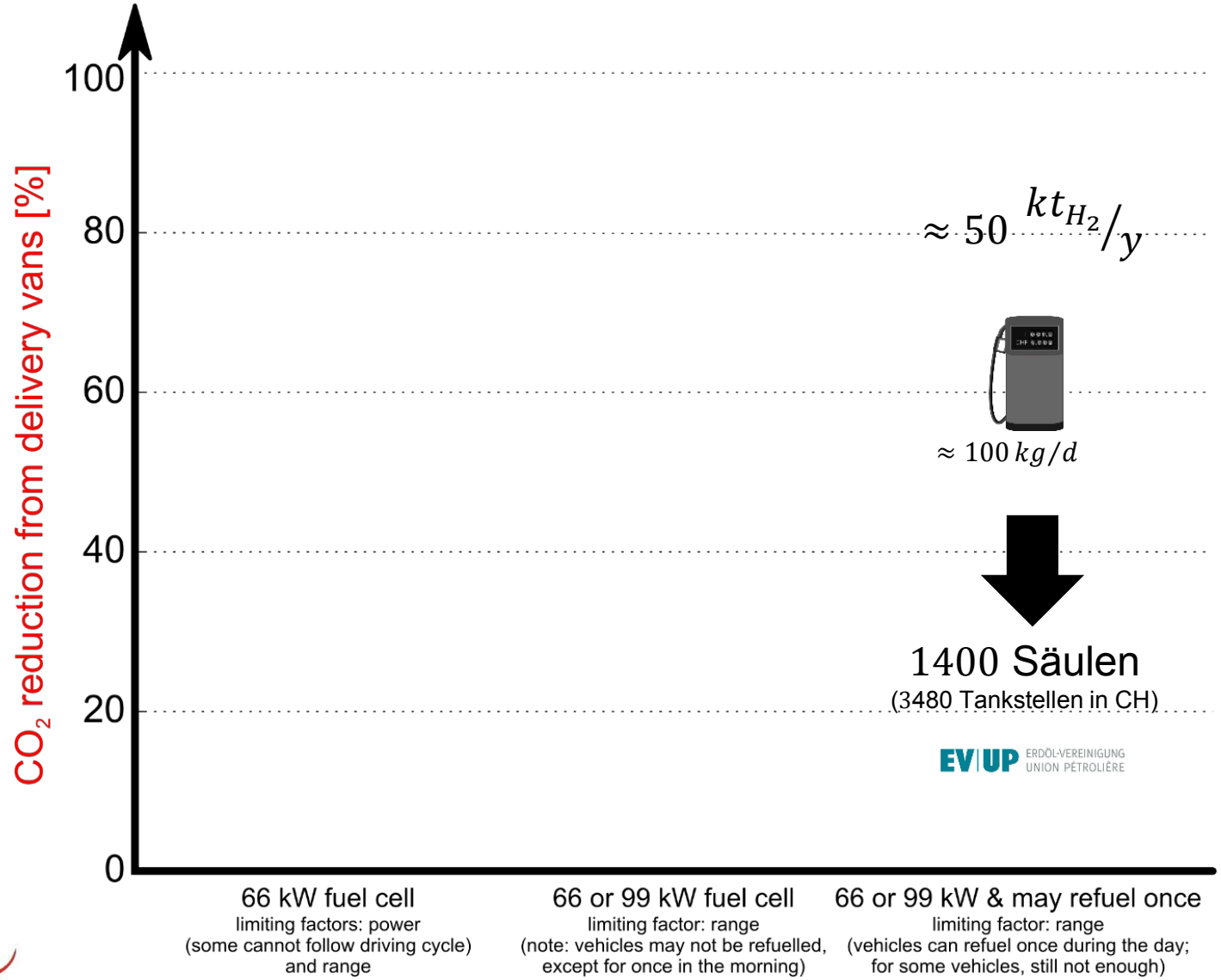
→ aerodynamics, tribology, new materials, hybridization

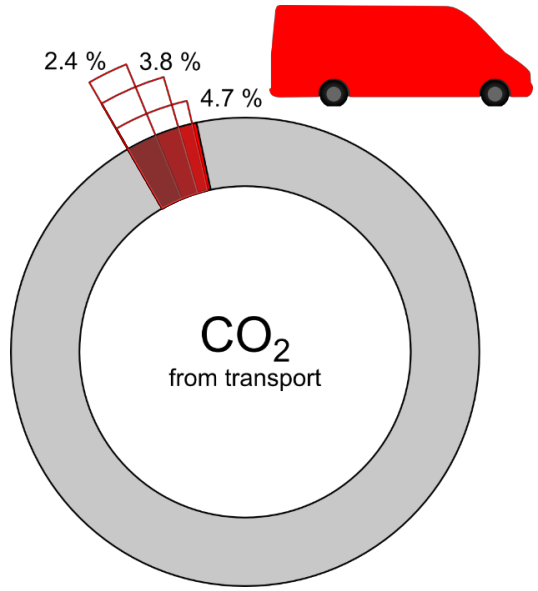
Path 2: «carrier substitution»

Replace fossil fuels by renewable energy carrier

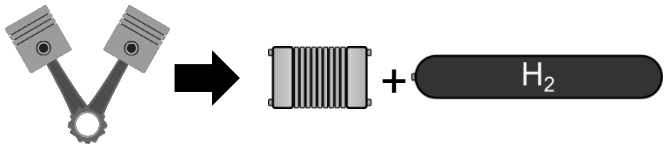
→ electrification via batteries or fuel-cells

EXAMPLE: fuel cell technology for light duty vehicles





Assuming CO2-neutral Hydrogen Production



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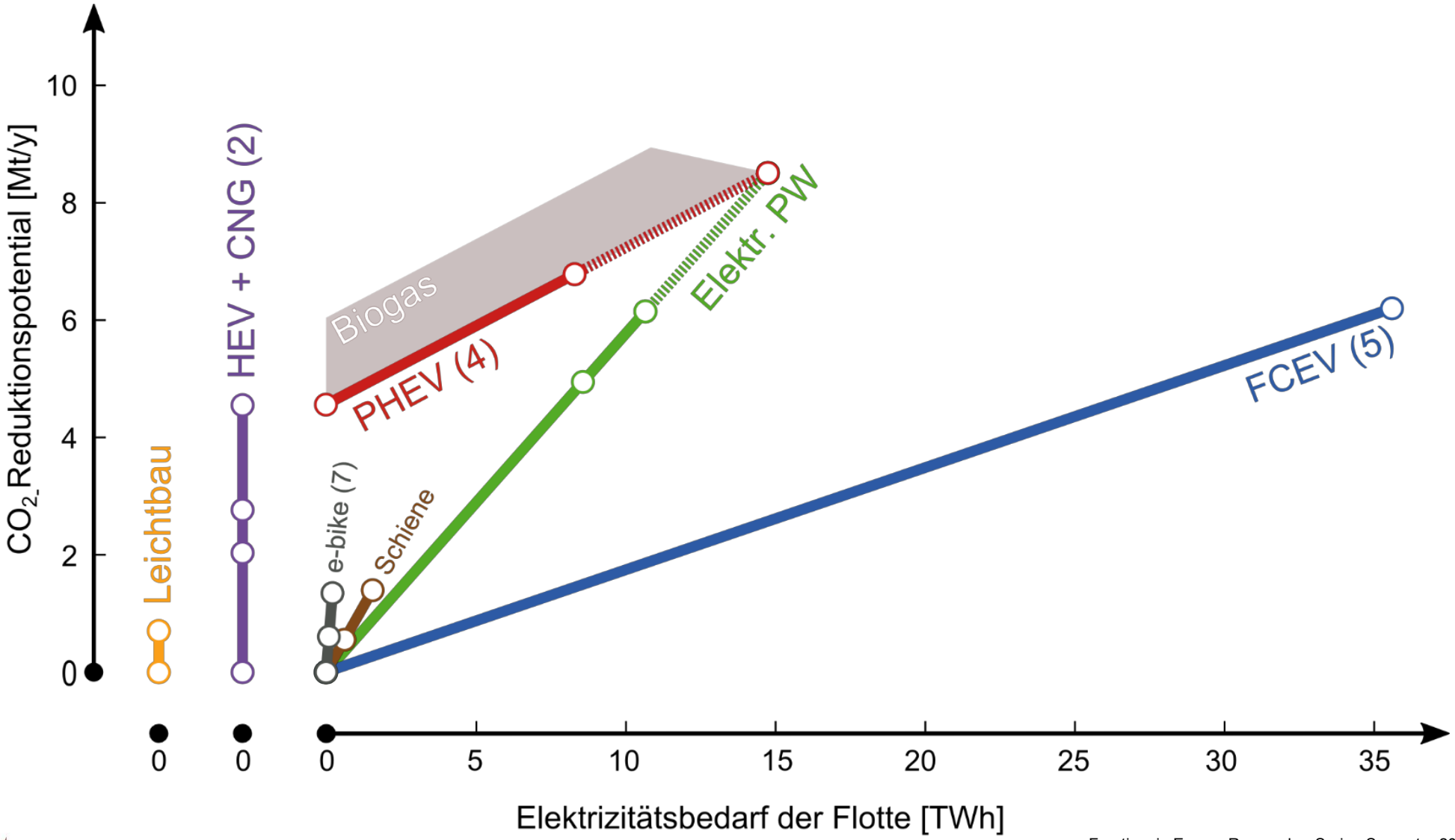
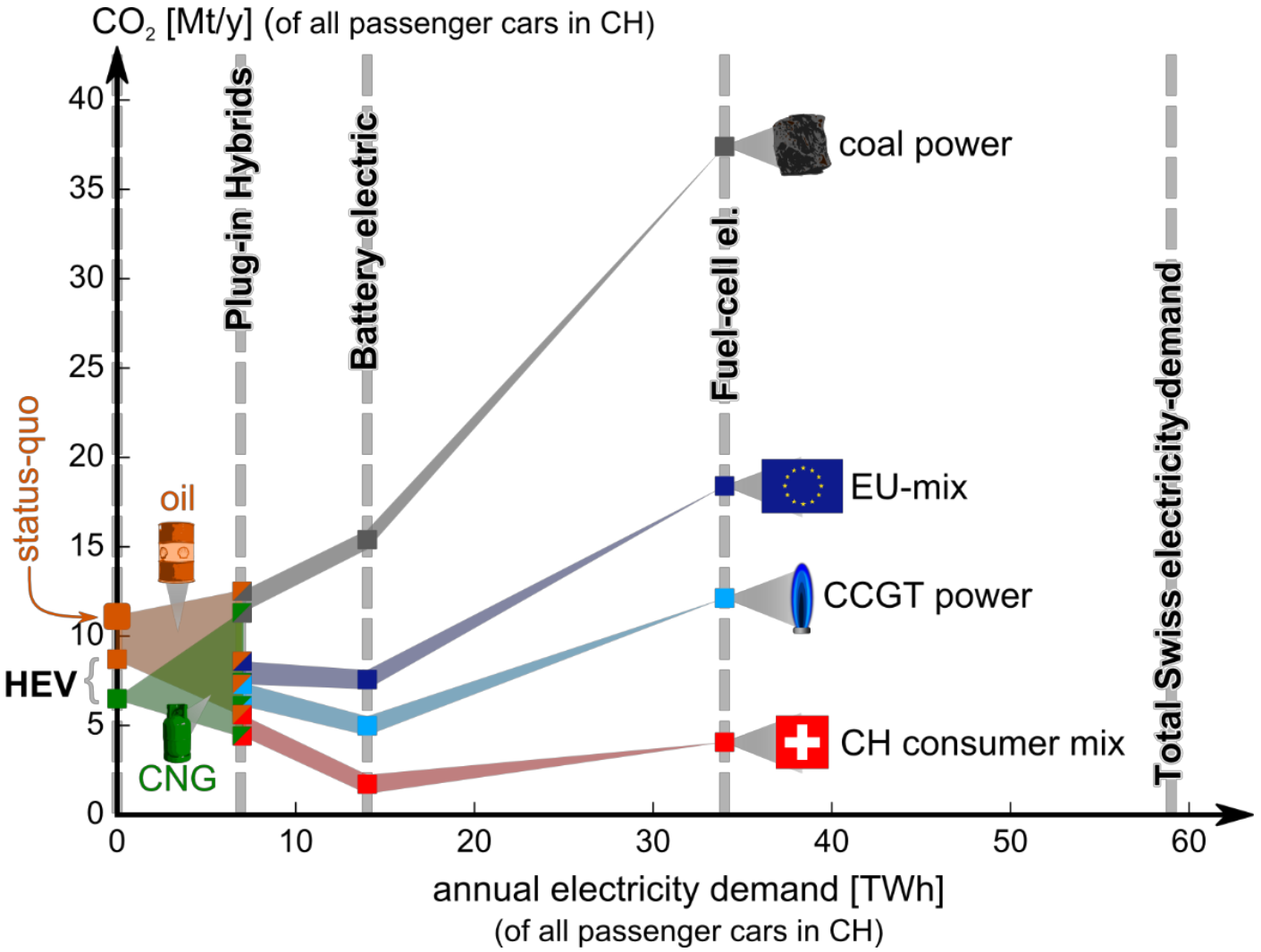
COMPILATION: CO_2 vs Electricity



Risiko: CO_2-Intensität der Elektrizitätsproduktion



Conclusion and Outlook regarding the energy-systemic model

- Many reliable and diverse data required and must be brought together
- Energy demand of Mobility shouldn't be expressed as a sum of average cars
- Maximum CO_2 mitigation potentials can be evaluated

Outlook:

- ESMOBIL-RED project:
  - Integrate real-world energy demand model → various propulsion technologies
  - Passenger car fleet operation → validation
- "Projections" into the future (freight and passenger, road based)
  - Mitigation strategies within the Energy perspectives 2050
- Infrastructure:
  - Link mobility model to the infrastructure; integration of renewables

Contact

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