ETH zürich

Towards an energy efficient and climate compatible future Swiss transportation system

SCCER School 2017

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Material: L. Küng, G. Georges, K. Boulouchos, SCCER Mobility

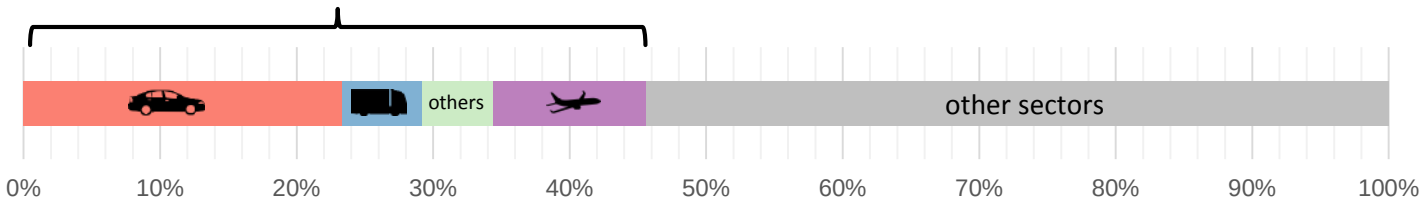
The current Situation

Why focus on Mobility?

→ large impact

- Transportation Sector (relative to other sectors):
  - highest CO_2 emissions

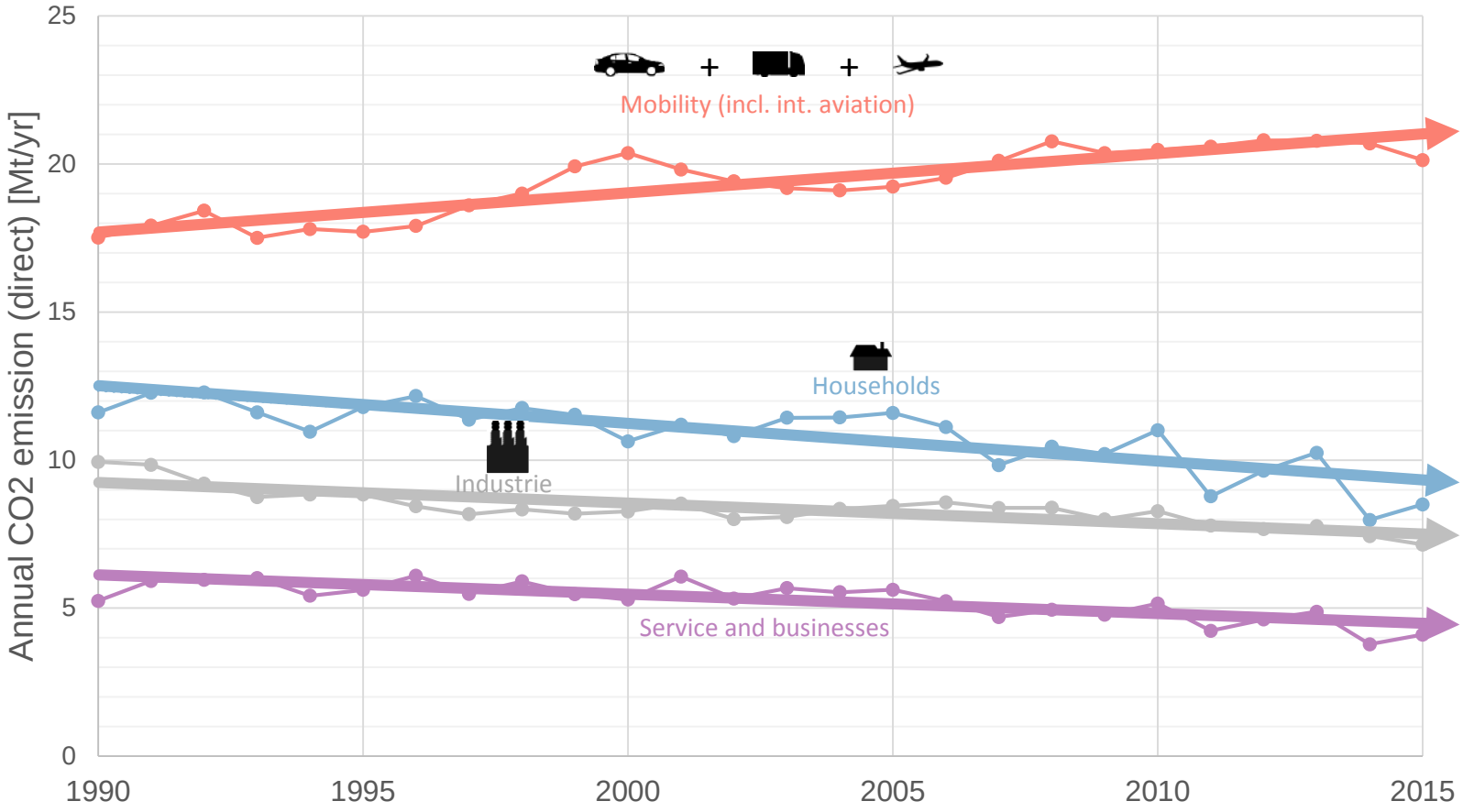
    2015 (BAFU): 45.6% of national emissions (incl. int. aviation)



Source: BAFU CO2-Statistik, April 2017 & BFS Gesamtenergiestatistik der Schweiz

Why focus on Mobility?

→ large impact



Source: BAFU, Entwicklung der Treibhausgasemissionen der Schweiz 1990-2015, https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/entwicklung_der_emissionenvontreibhausgasenseit1990april2016.xlsx.download.xlsx/entwicklung_der_emissionenvontreibhausgasenseit1990.xlsx

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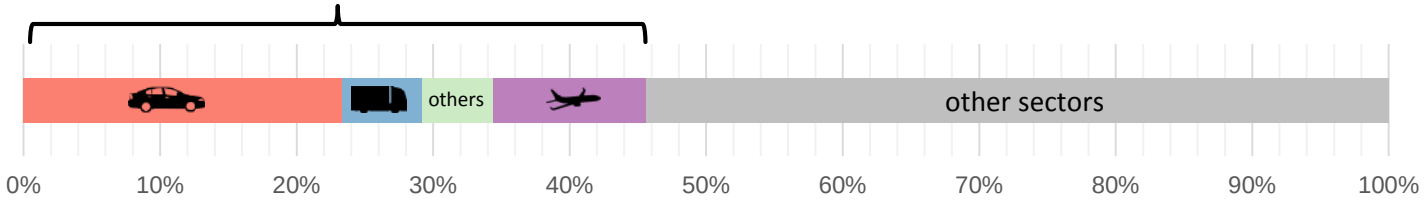
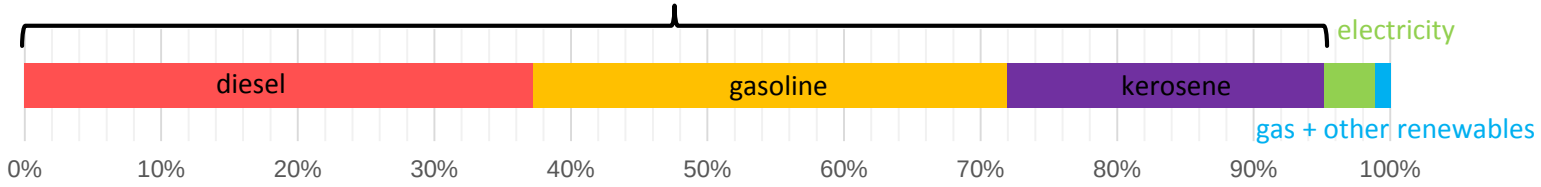


  - highest demand in final energy

    2015 (BFS): 36% of national energy demand (households: 27.7%)
  - extreme dependency on fossil products

    2015 (BFS): 95.1% of energy demand based on oil



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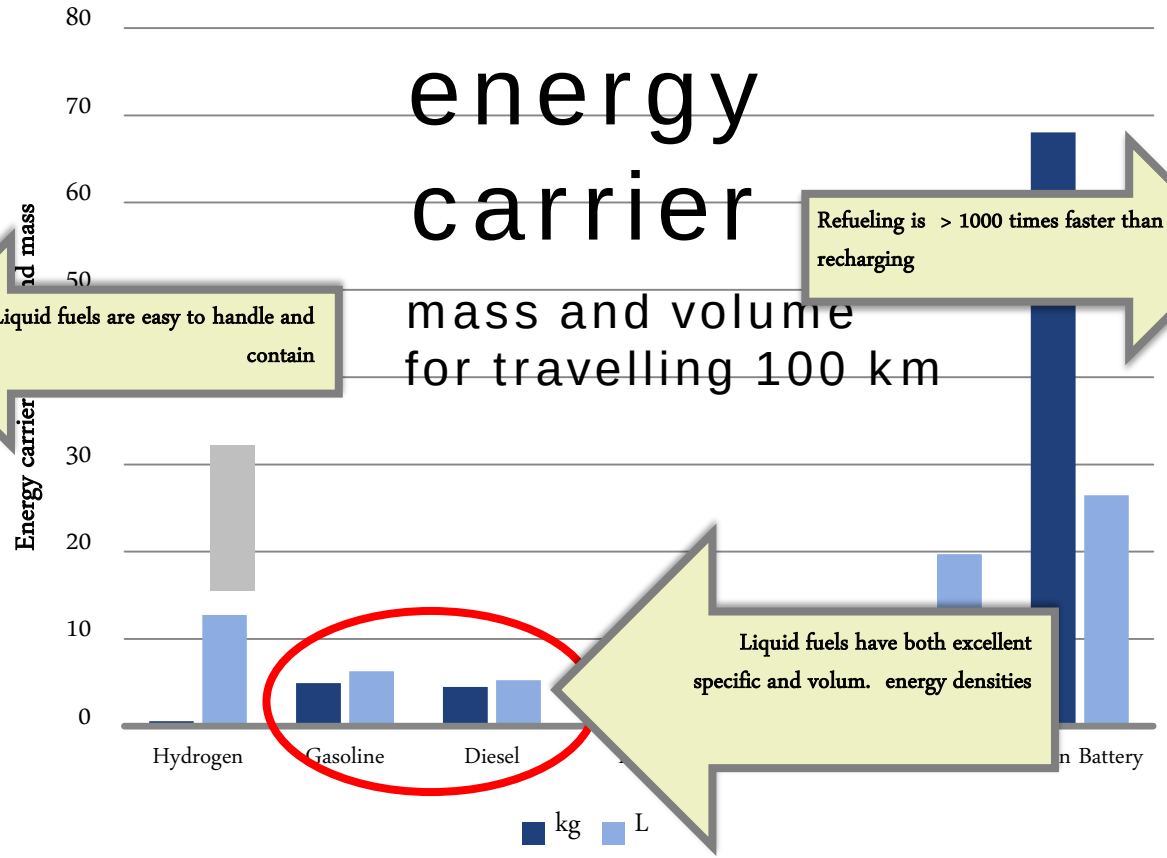
Liquid hydrocarbon fuels

→ a perfect match for mobile applications



~15 s

~1.3 h

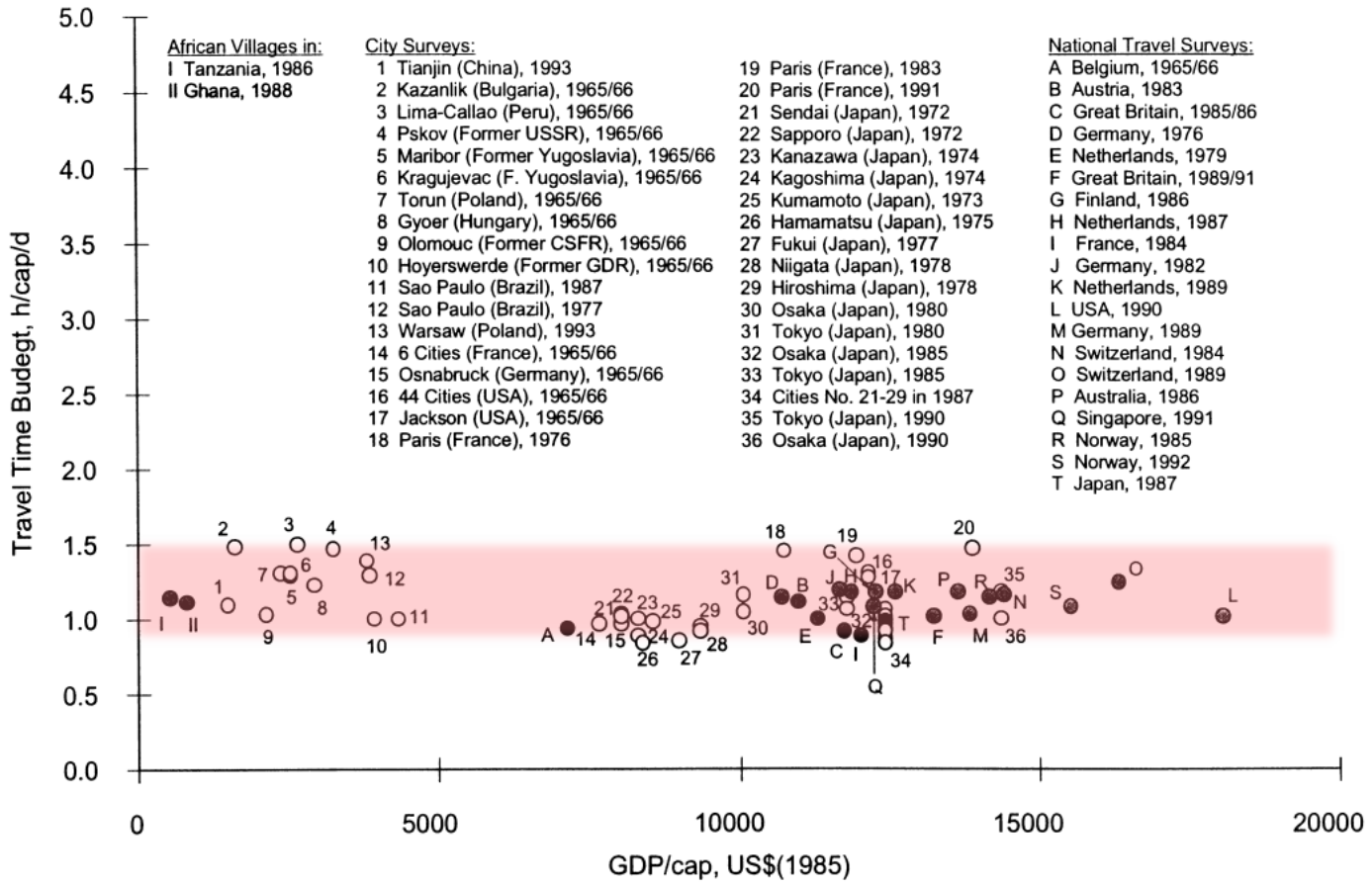
~5 h

Trends / Evolution

→ business as usual

Evolution of mobility demand?

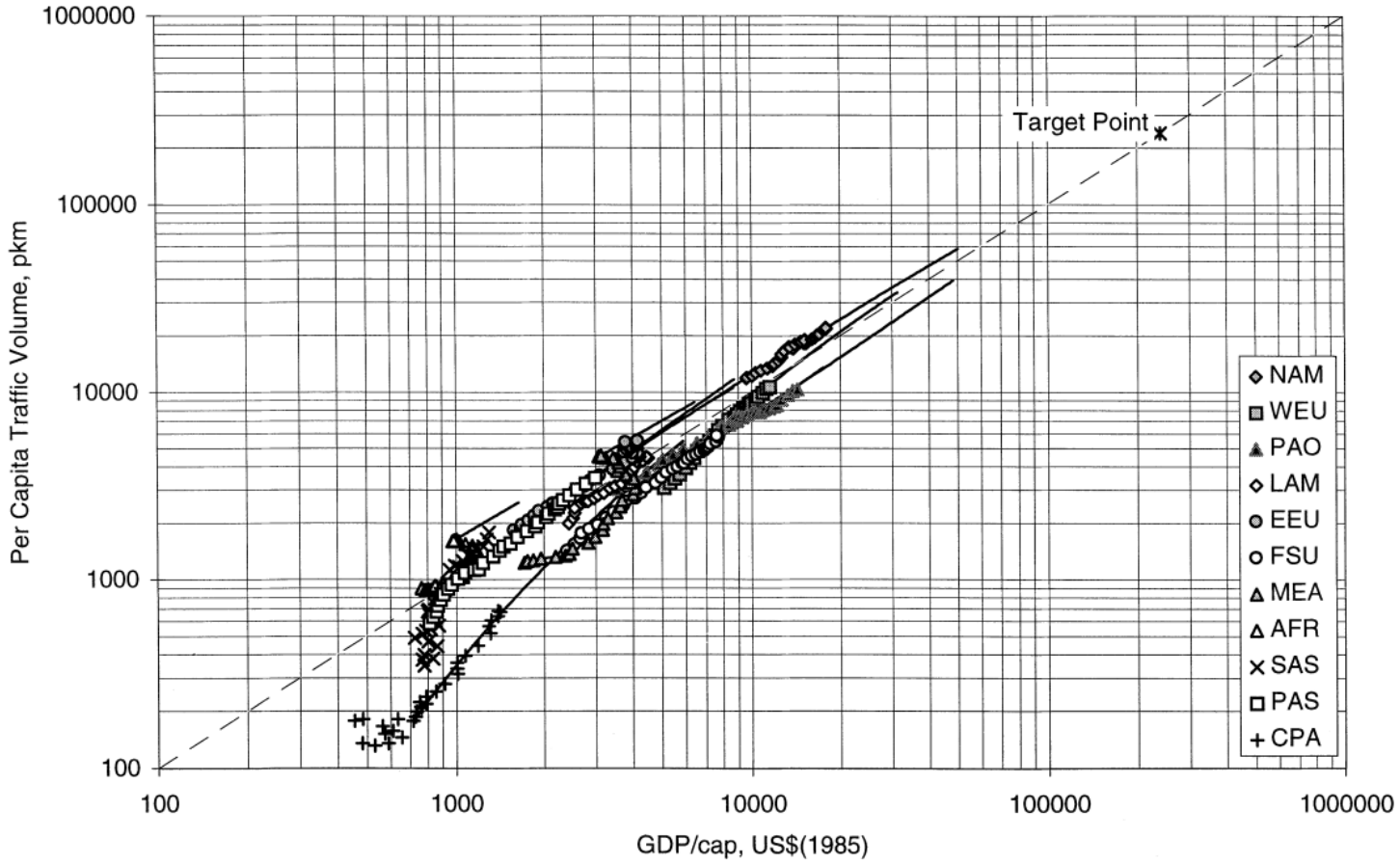
→ average travel budget +/- global constant



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

Time is BIP independent, Distance is not

→ wealth leads to increasing mobility demand



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Switzerland

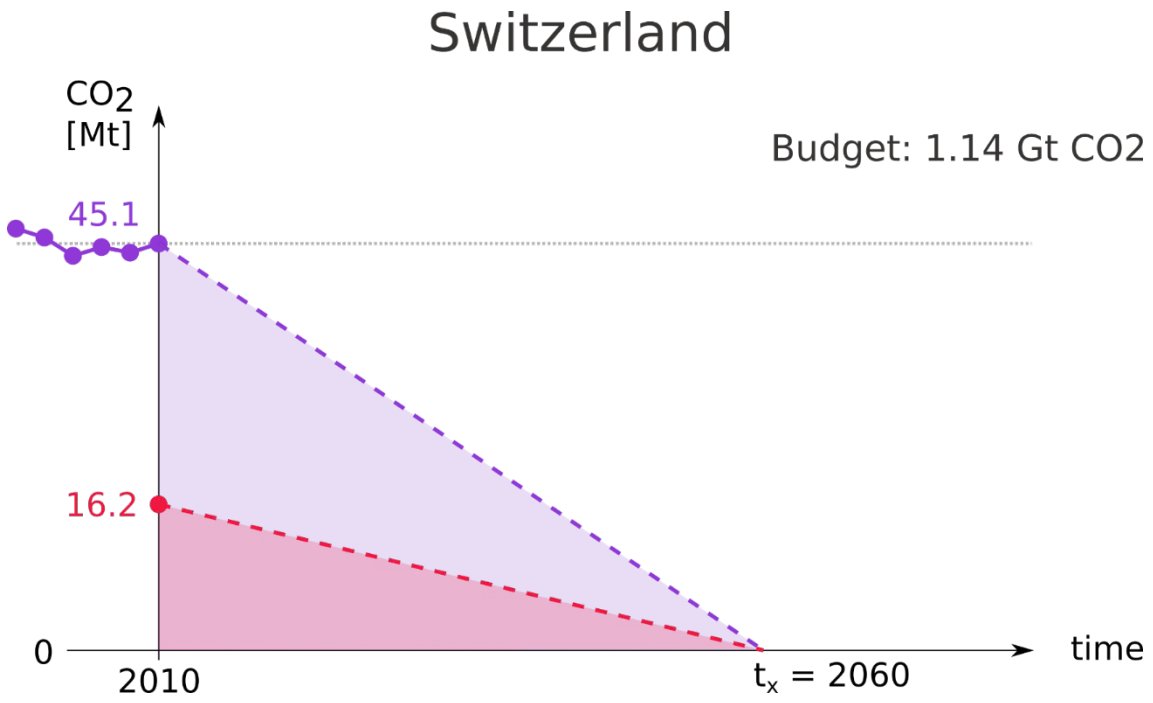
→ national transport perspectives

Source: ARE, Perspektiven des Schweizerischn Personen und Gütervverkehrs bis 2040

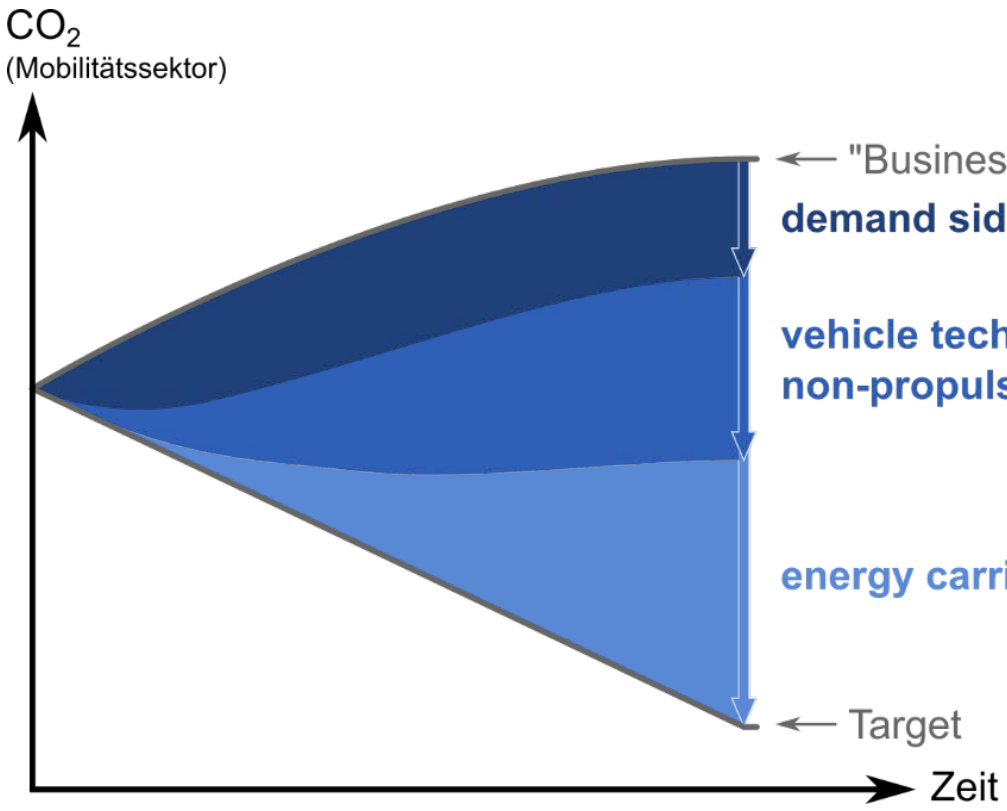
Climate policy
→ Road to sustainability

Time horizon for decarbonizing: CO_2 Budget

- IPCC 2°C (66%) world carbon budget in 2010:
  1000 Gt CO2
- «per-capita» distribution results in 1.14 Gt CO2 for Switzerland
- Assuming linear reduction: Budget will last until 2060
- Road-based mobility sector must contribute with same rate



The 3 levers for CO_2 reduction in mobility sector



demand side measures
- «Mobility-pricing»
- Spatial planning
- Teleworking/shopping
- «Sharing»

year

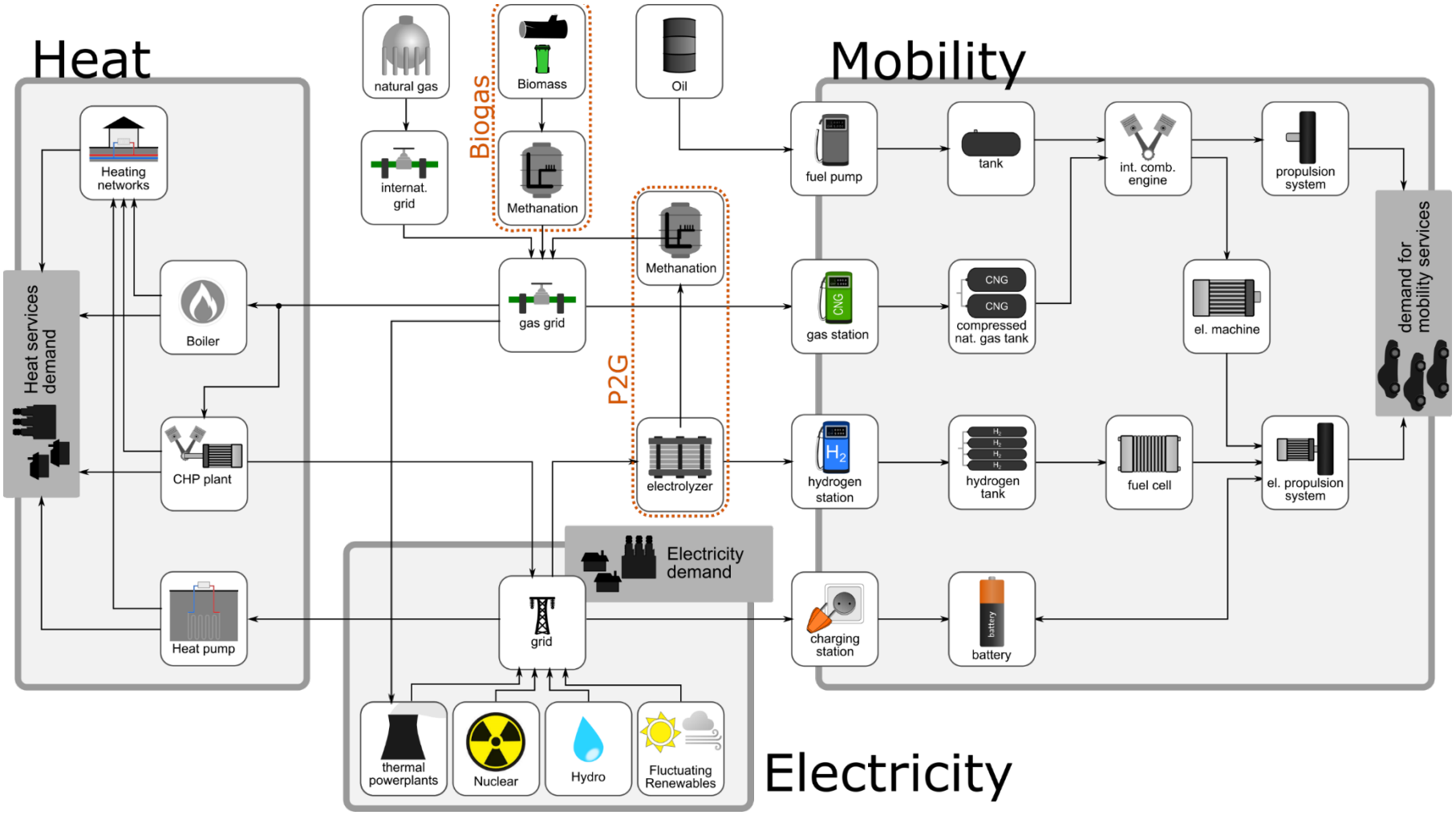
vehicle technology and non-propulsive loads
- Improved Components
- «Light weighting»
- Smaller vehicles
- Hybridization

~15 years

energy carrier substitution
- Natural Gas
- Synthetic fuels
- Hydrogen
- Electricity

decades

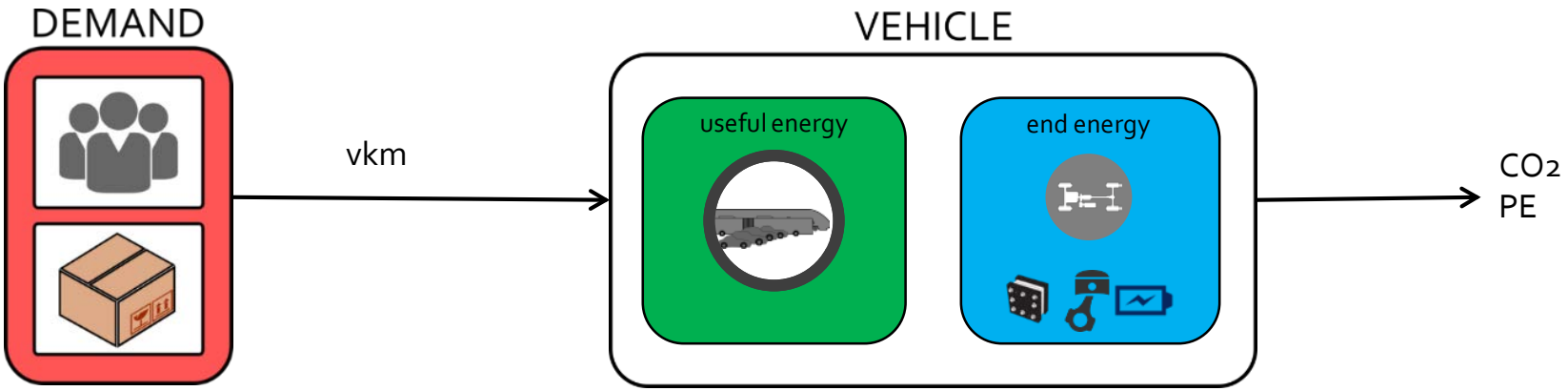
Is it really so easy?


Heat
Mobility
Electricity
natural gas
Biomass
Oil
Biogas
internat. grid
Methanation
Methanation
P2G
Heating networks
Heat services demand
Boiler
gas grid
CHP plant
electrolyzer
Heat pump
Electricity demand
grid
thermal powerplants
Nuclear
Hydro
Fluctuating Renewables
fuel pump
tank
int. comb. engine
propulsion system
gas station
CNG
CNG
compressed nat. gas tank
el. machine
demand for mobility services
hydrogen station
hydrogen tank
fuel cell
el. propulsion system
charging station
battery

We need strategic planning
→ What are potential impacts?

What are maximum reduction potentials?

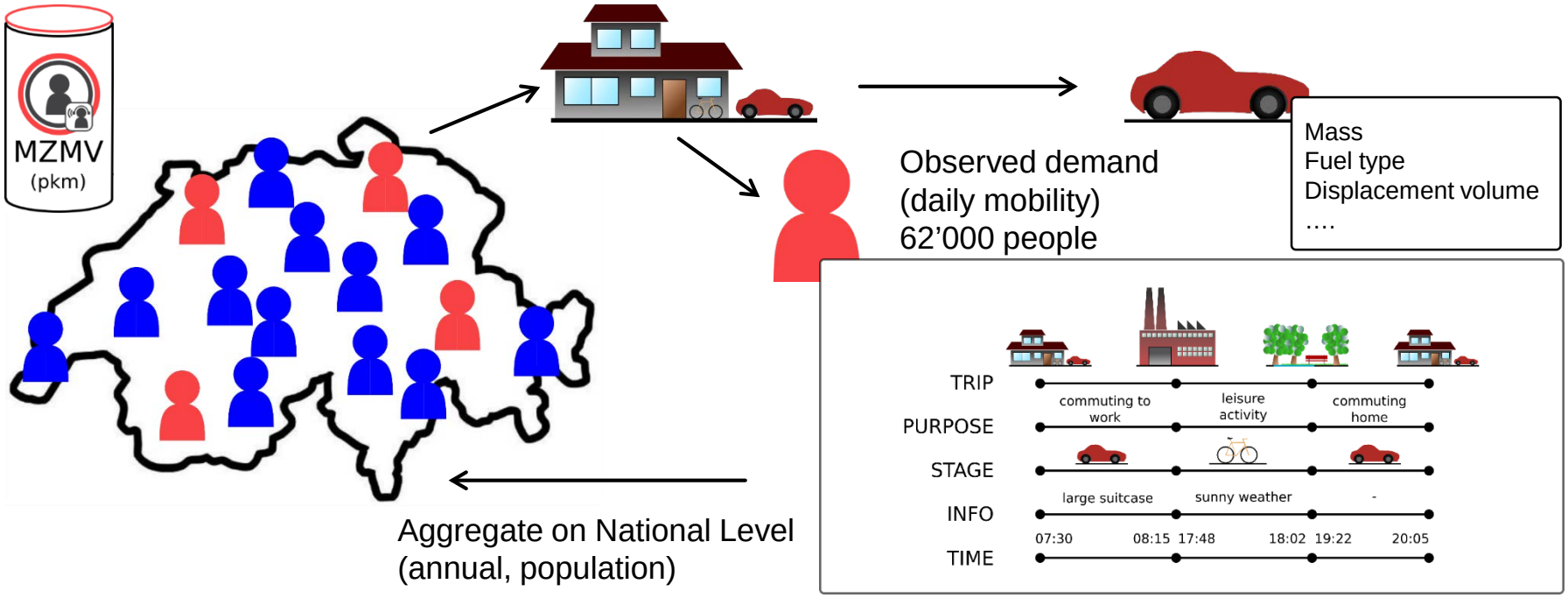
- Mobility system consisting of demand and supply
- Bottom-up representation



- Focus on: **Passenger cars**
- Isolated Interventions: change of “status-quo”, apply to the maximum
- No rebound effects, technology acceptance or costs are considered
- Cost function: Additional electricity consumption of mobility sector

Demand: Mikrozensus Mobilität und Verkehr 2010

National survey on Mobility → Demand: profiles, weighting factors and vehicle information



From vkm to final energy

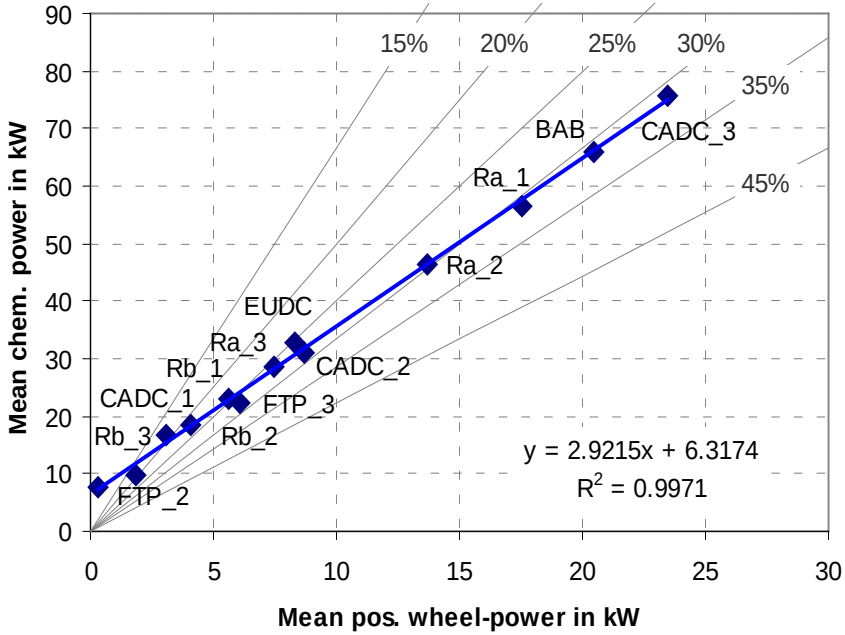
→ Vehicle Energy Demand Simulation

- Aim: fast but based on physical concepts
- Propulsive vehicle force:

$$F_{motor}(v,\dot{v}) = (\boldsymbol{m_V} \cdot \dot{\boldsymbol{v}}) + \left(\frac{1}{2} \cdot \rho_{air} \cdot \boldsymbol{c_d} \cdot \boldsymbol{A_f} \cdot \boldsymbol{v}^2\right) + (\boldsymbol{c_r} \cdot \boldsymbol{m_V} \cdot g)$$

Acceleration (F_{acc}) | Aerodynamic drag (F_{aero}) | Rolling resistance (F_{road})

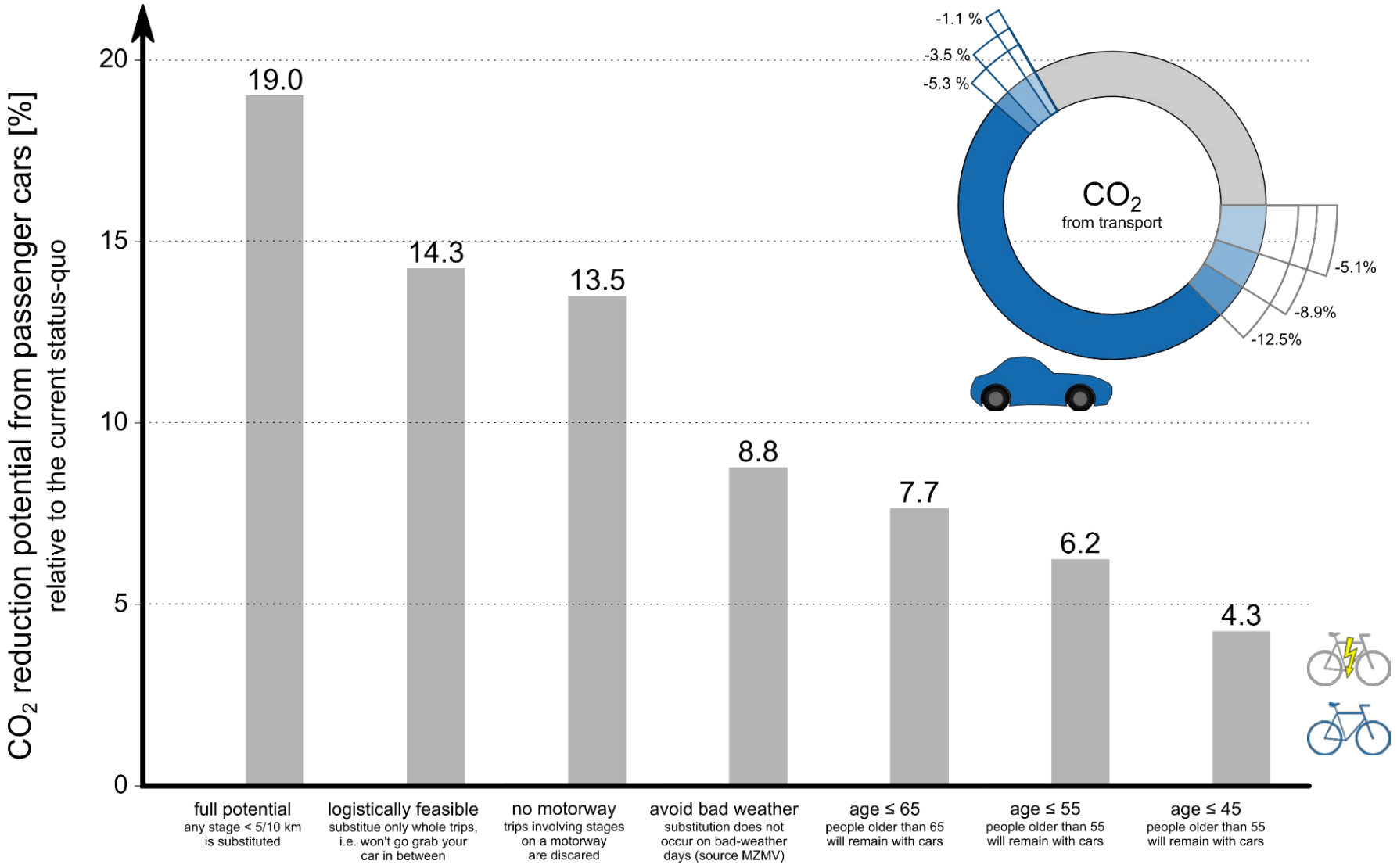
- Require Driving Cycle (NEDC, WLTP)
- Conversion Efficiency based on mean Willans-Approach
  → dynamometer measurements of Empa



Source: C. Bach, P. Soltic, CO2 Reduction and Cost Efficiency Potential of Natural Gas Hybrid Passenger Cars, SAE International (2011) 1-10.

Example:
Change in Mobility behavior

Demand: short car trips → bicycle

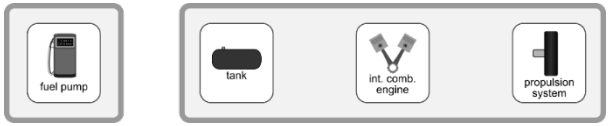


Example:
Change in Mobility supply

Intervention: Hybridization and compressed natural gas (CNG)

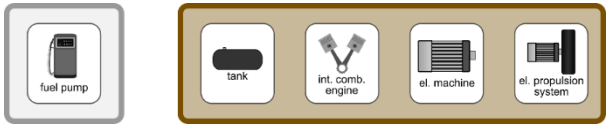
Status-Quo:

Diesel + Gasoline

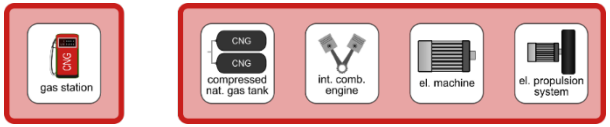


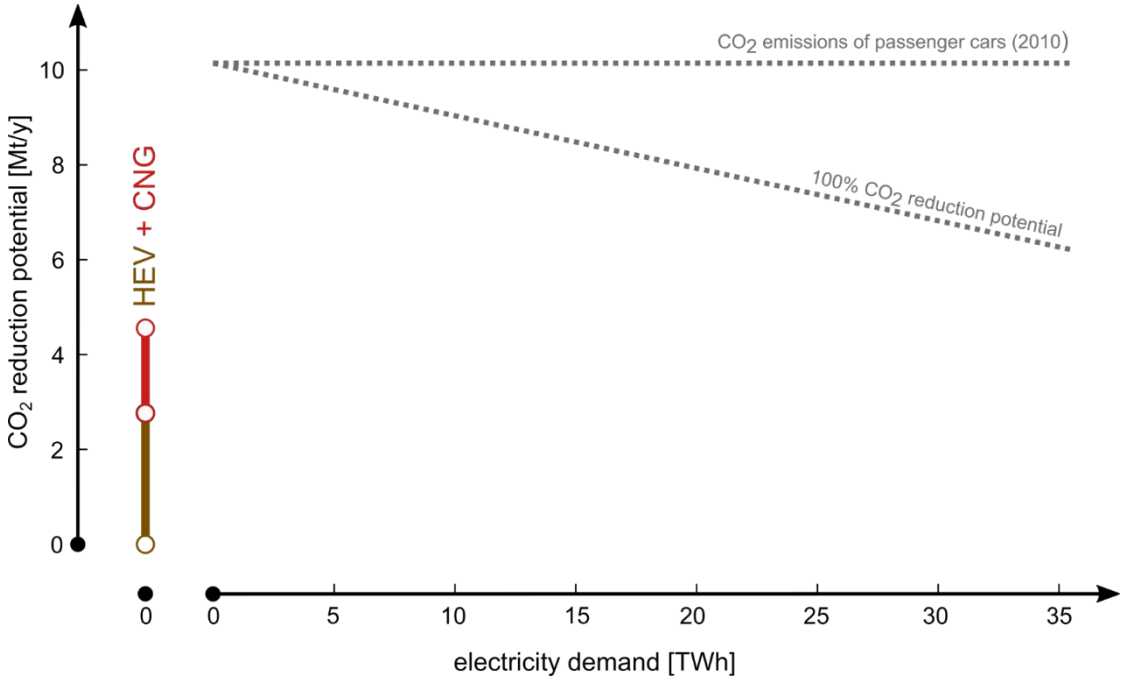
1) Hybridization:

Substitute entire fleet



2) Fuel Switch to CNG

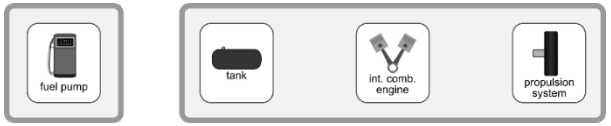




Intervention: Battery electric vehicles (BEV)

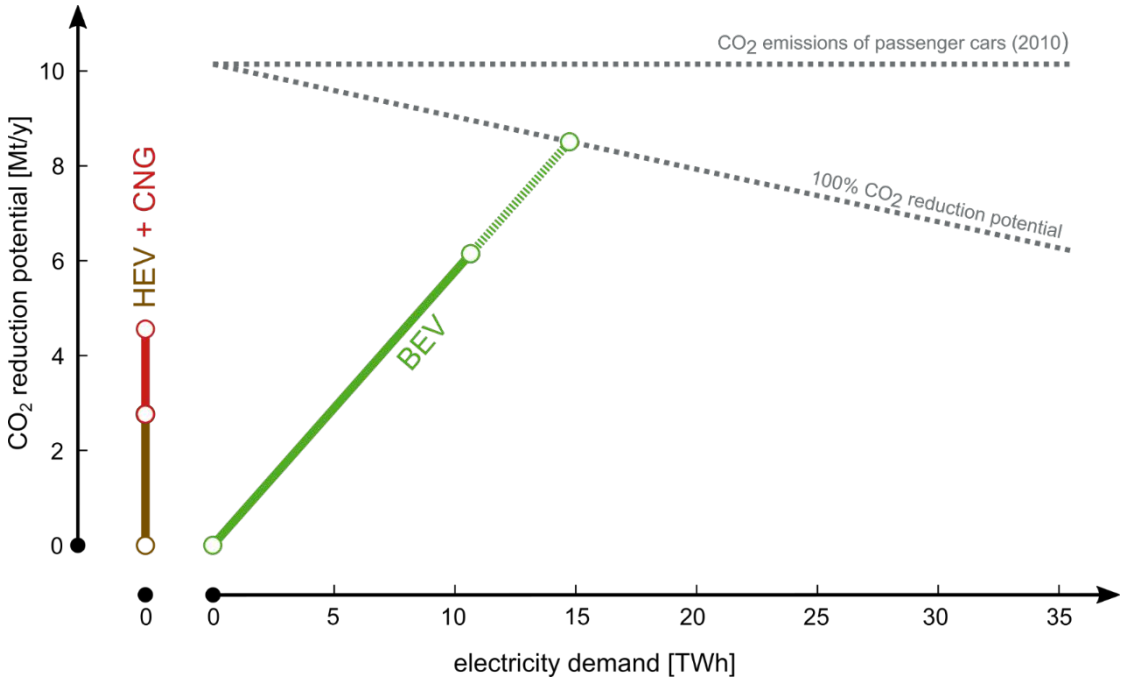
Status-Quo:

Diesel + Gasoline



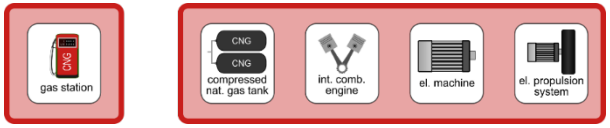
Battery electric vehicles

Substitute where possible



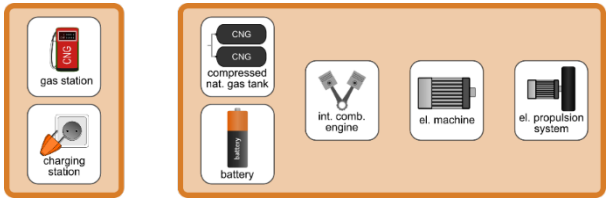
Intervention: Plug-in hybrid electric gas vehicles (PHEV CNG)

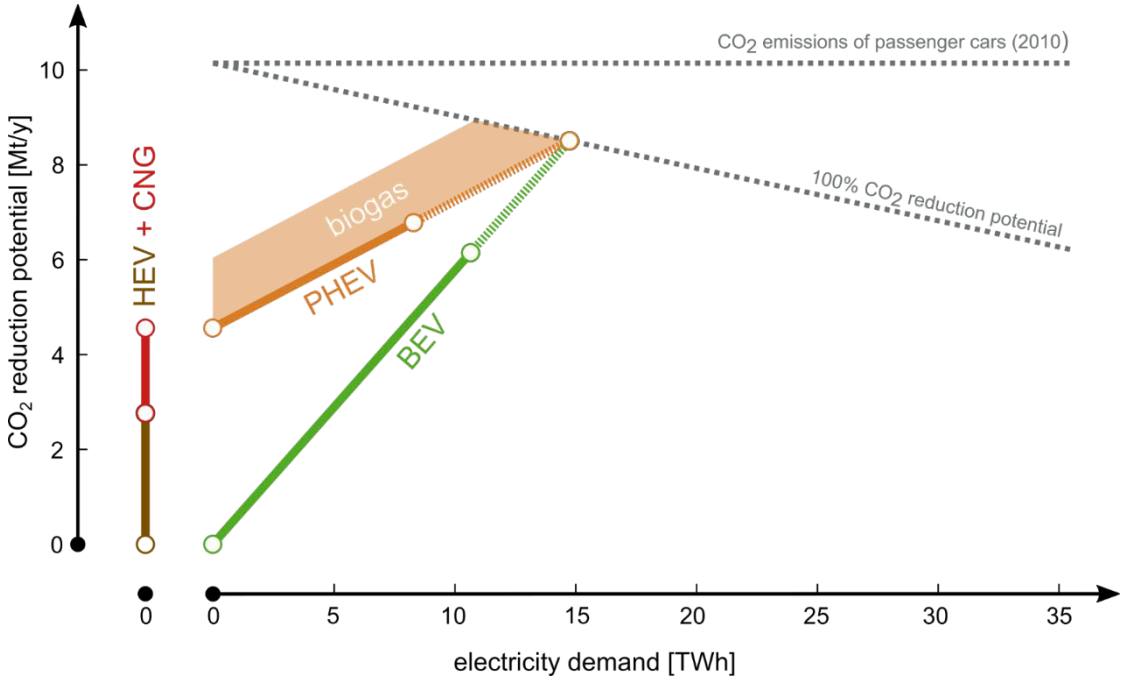
Gas hybrid



Plug-in gas hybrid vehicles:

Substitute entire fleet

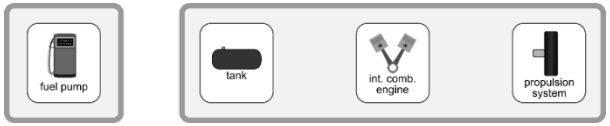




Intervention: Fuel cell electric vehicles (FCEV)

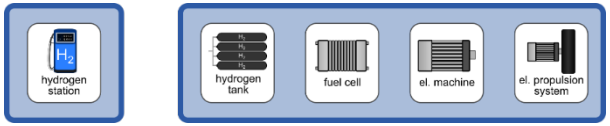
Status-Quo:

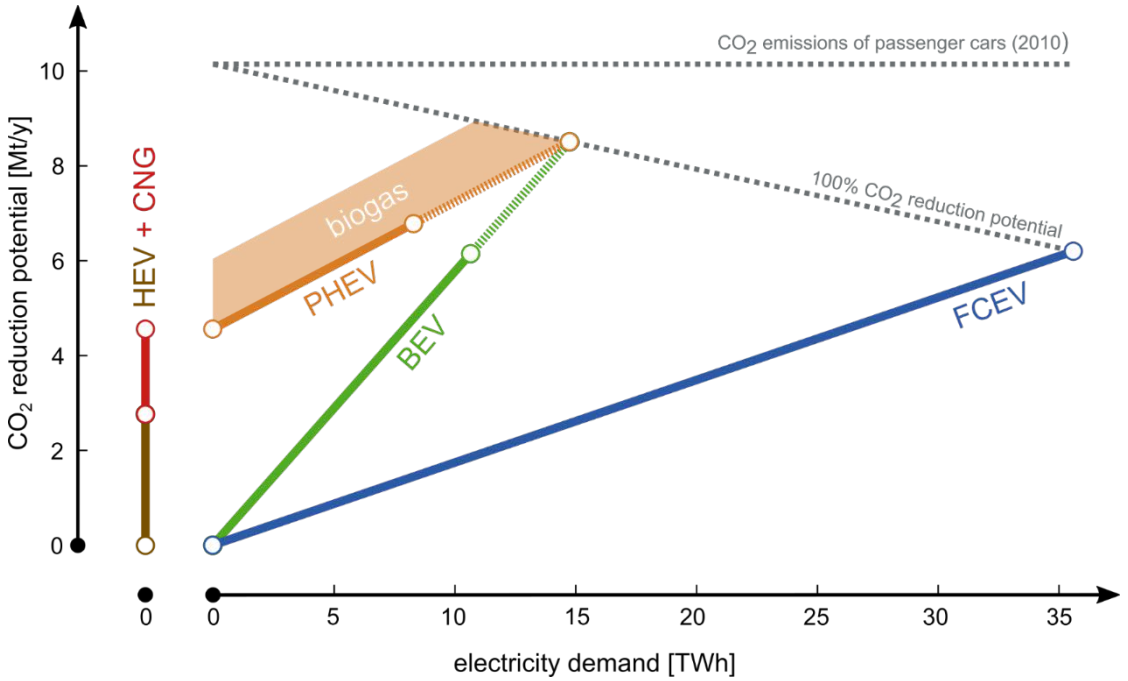
Diesel + Gasoline



Fuel cell electric vehicles:

Substitute entire fleet





Alternative technologies

- Alternative technologies exist for passenger cars!
  - Two reduction paths: **evolutionary** and **disruptive**

- Main challenges:
  - Costs and speed of transition
  - Infrastructure
    - → Passenger cars ≈ 15 years
    - → Trucks & busses ≈ 10-20 years
    - → Ships & airplanes ≈ 20-30 years
    - → Electricity generation & power plants ≈ 20-50 years
  - Acceptance and availability (policy)
  - Large burden for electricity supply;
    - → parallel evolution of energy supply and mobility sector required

Alternative technologies

- Alternative technologies exist for passenger cars!
  - Two reduction paths: **evolutionary** and **disruptive**
- Not addressed: effects of vehicle usage, life time and embedded emissions
- Important:
  - passenger cars are one part of the mobility sector → Heavy-duty freight trucks
  - transportation occurs globally
    - → International Aviation
    - → Maritime freight transport

The global challenge

Long-range, heavy-duty global transport modes

Mode / sector	2010 share of transport GHG emissions	Growth 2010-2015	Projected increase 2030 (compared to 2010)	Projected share 2030 (if all other transport sector emissions stay constant)
Passenger air travel	10.6%	37.5% (pkm)	3.57 x	27%
Maritime freight	9.3%	23.1% (tkm)	2.3 x	16%

source: IPCC 2014

→ Direct electrification not possible in these two sectors → **renewable chemical energy carriers** (H2, CxHy) will be a MUST

Conclusion & Outlook

- Decarbonization of the transport sector is an absolute necessity, but also a huge challenge (in Switzerland and worldwide)
- Innovation on both the demand and supply side must be pursued in parallel
- Technology will be crucial – **evolutionary** and **disruptive** paths must be well orchestrated for optimal CO2 reduction trajectories
- Socio-economic policy must be designed in line with these targets