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# Capacity Area B2: Integrated Assessment of Mobility Systems

Stefan Hirschberg et al.
Paul Scherrer Institut

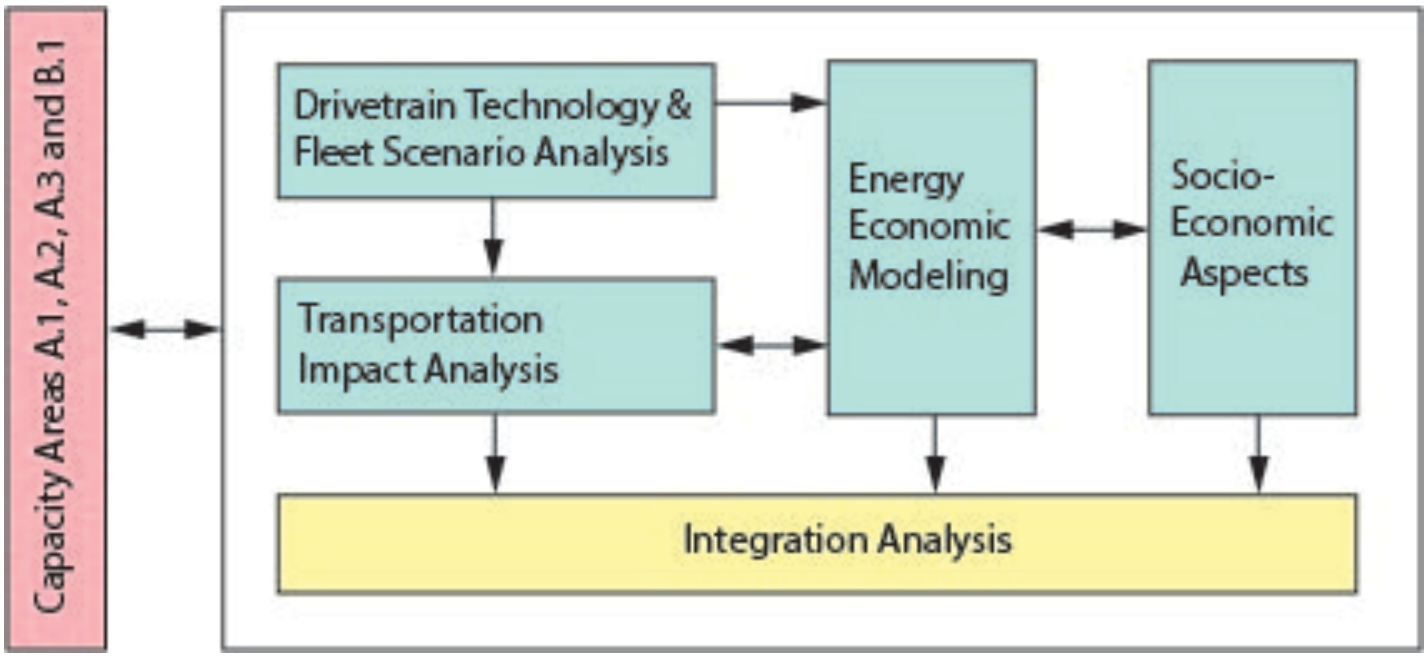
# Integrated Assessment of Mobility Systems (CA B2)

LAV
Laboratorium für Aerothermochemie und Verbrennungssysteme
Aerothermochemistry and Combustion Systems Laboratory

PAUL SCHERRER INSTITUT
PSI

University of Applied Sciences and Arts
of Southern Switzerland
SUPSI

zh aw
School of Engineering
INE Institute of Sustainable Development




## Methods and Tools:

Vehicle Simulation, Life Cycle Assessment, Impact Pathway Approach, Comparative Risk Assessment, Learning Curves, Partial Equilibrium Modeling, Cost-Benefit Analysis, Multi-Criteria Decision Analysis, Living Labs.

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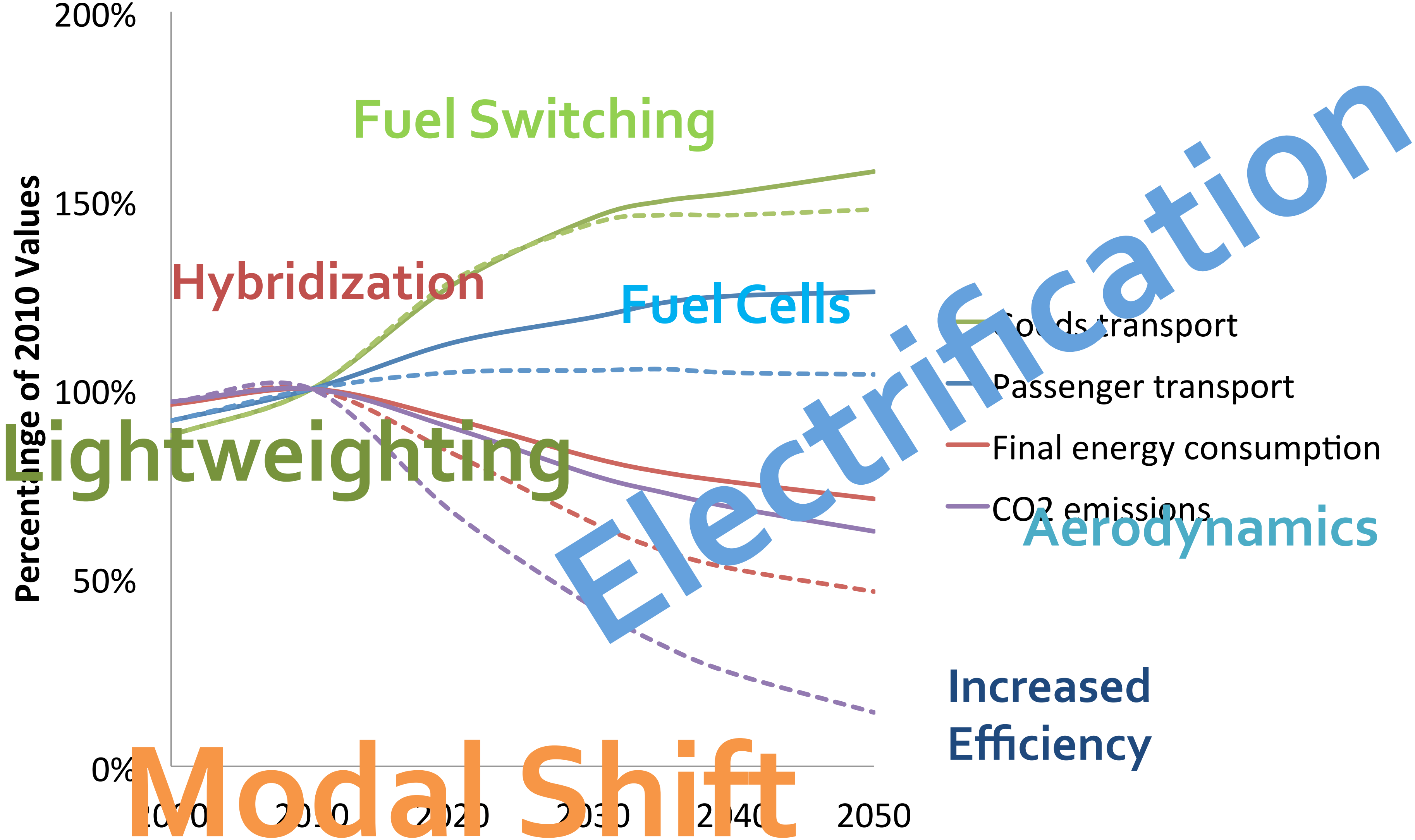
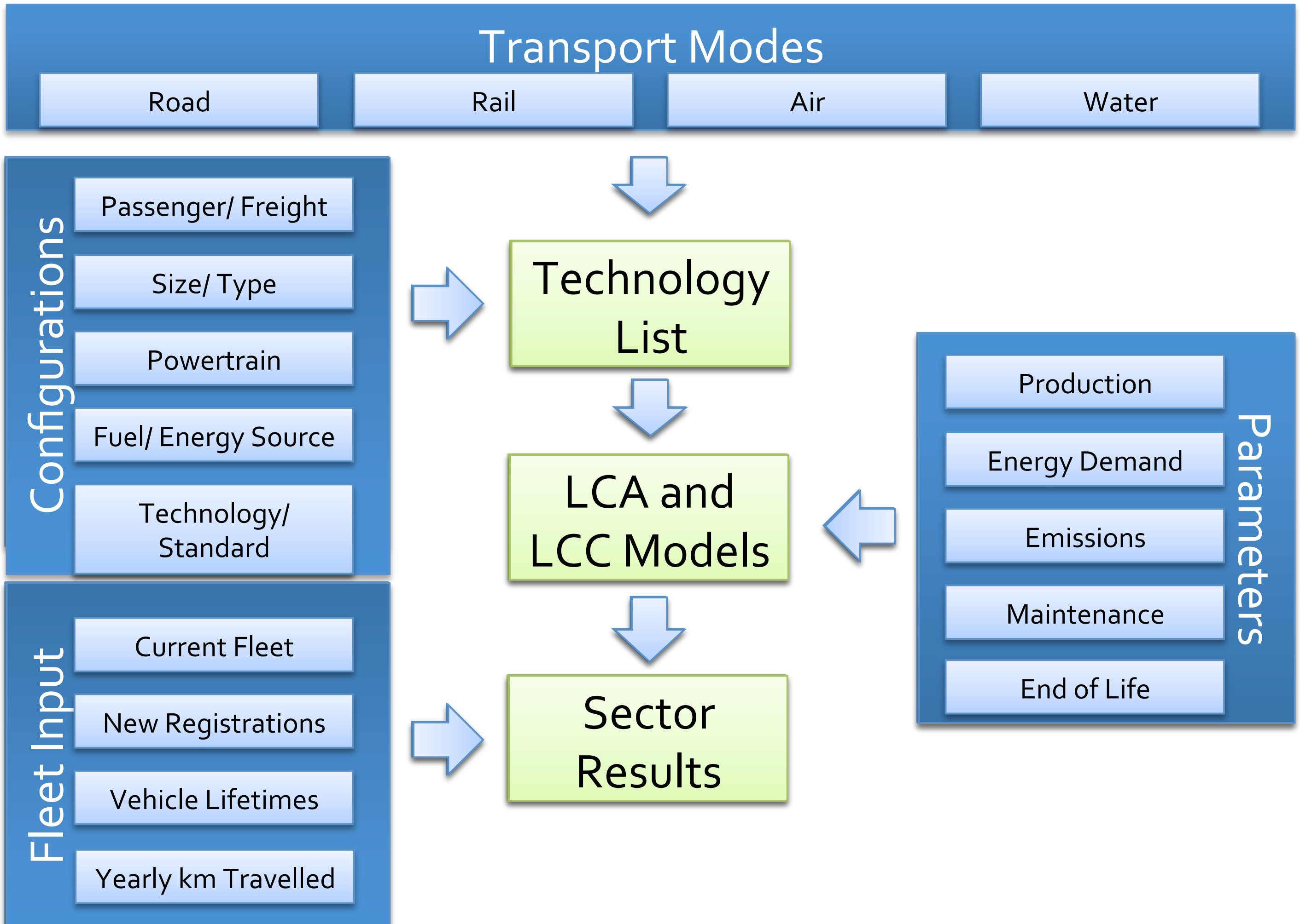
# Motivation – Swiss Energy Strategy 2050




Data Source: Prognos 2012

# Methodology



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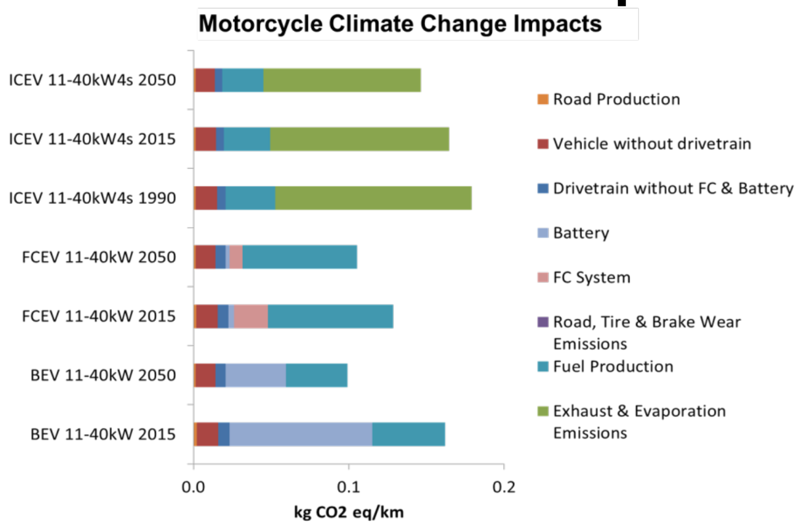
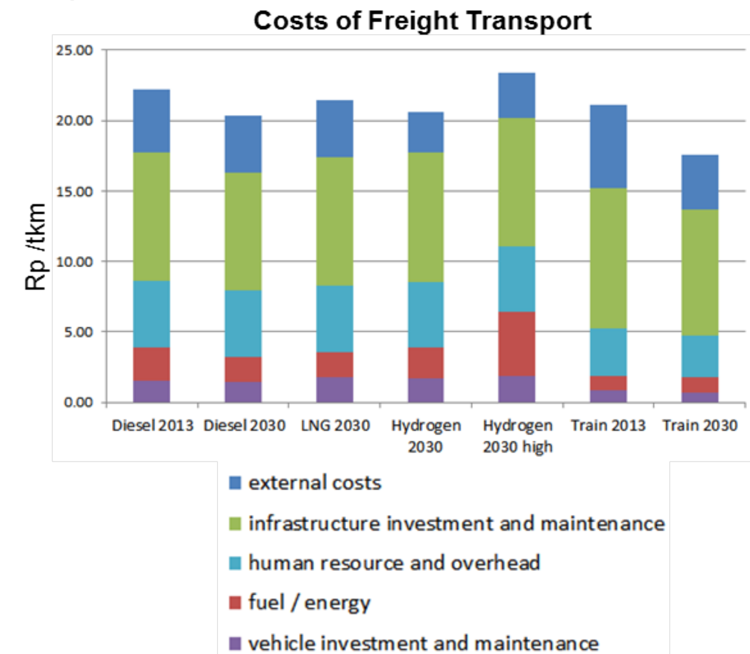
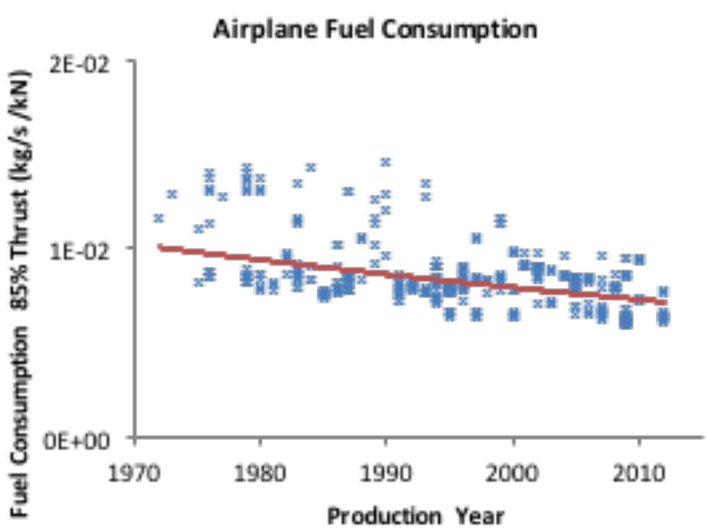
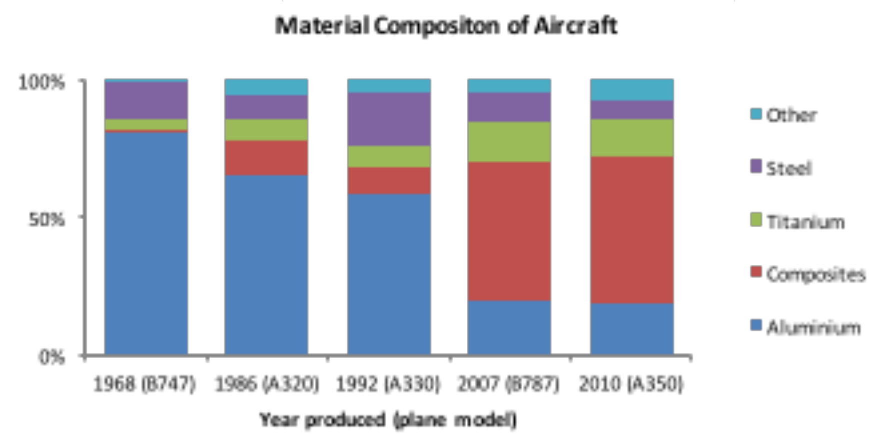
# LCA & Costs of Transport Technologies- Results Examples



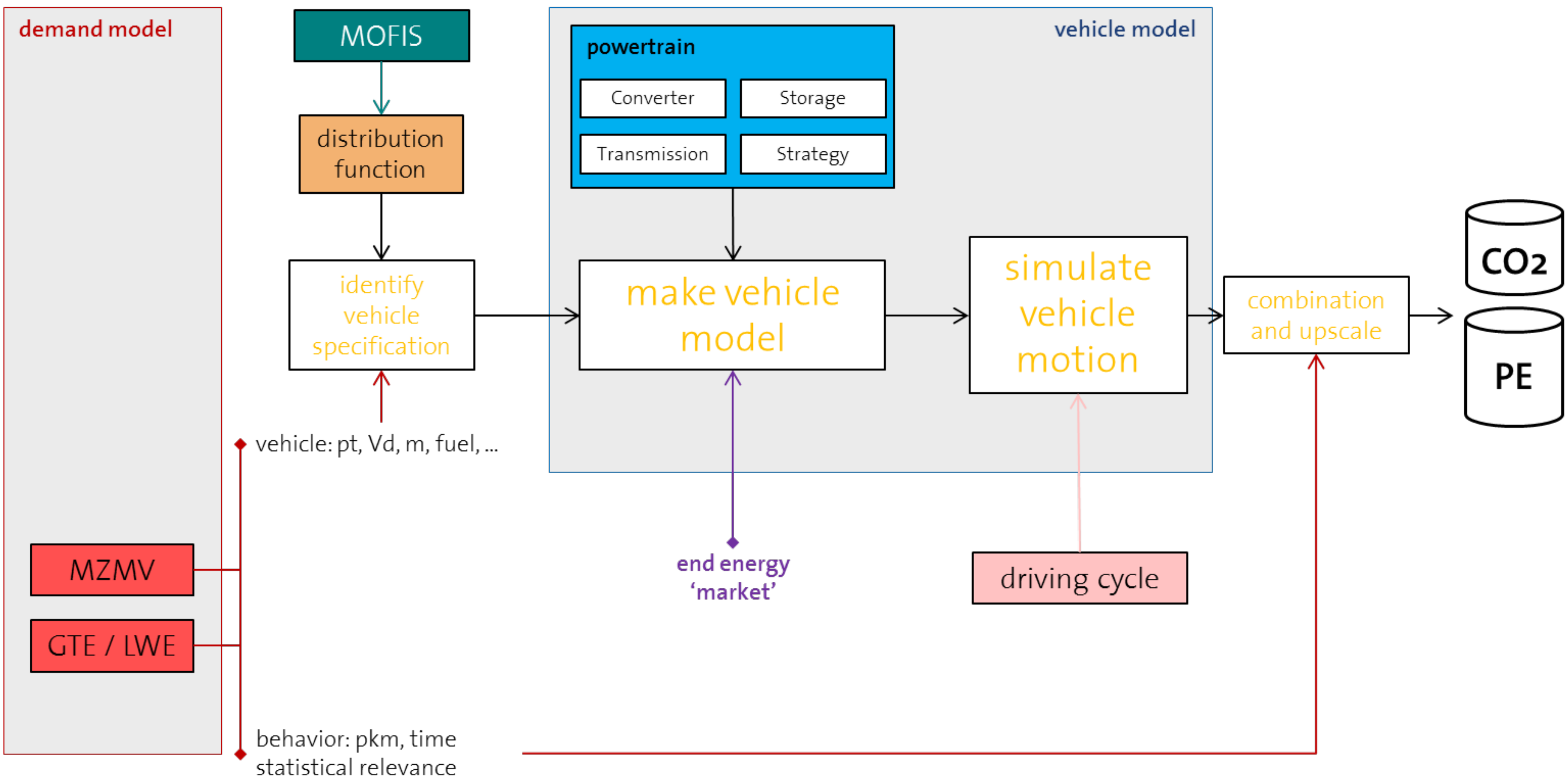
# Overview over ETHZ-LAV activities in CA-B2:
## vehicle simulation & project «strategic guidance»

- Vehicle end-energy demand data → all vehicles in the fleet
  - **Output:** energy demand of vehicles in operation
  - **Means:** simulation based on physical models
  - **Extent:** all vehicles in the fleet:
    - Types: passenger cars, medium & heavy duty vehicles, motor-bikes
    - Technologies: conventional and electrified powertrain layouts
- Project "Strategic Guidance" → systemic perspective
  - **Output:** of options of influencing mobility system (interventions)
    - and their effectiveness in terms of $CO_2$/primary energy reduction
  - **Means:** energy/$CO_2$ balance over the entire mobility system:
    - scaling the energy-demand data → national level
    - modifying boundary conditions (such as demand) to simulate interventions

# ETHZ-LAV activities in CA-B2:
## Status / Research progress:

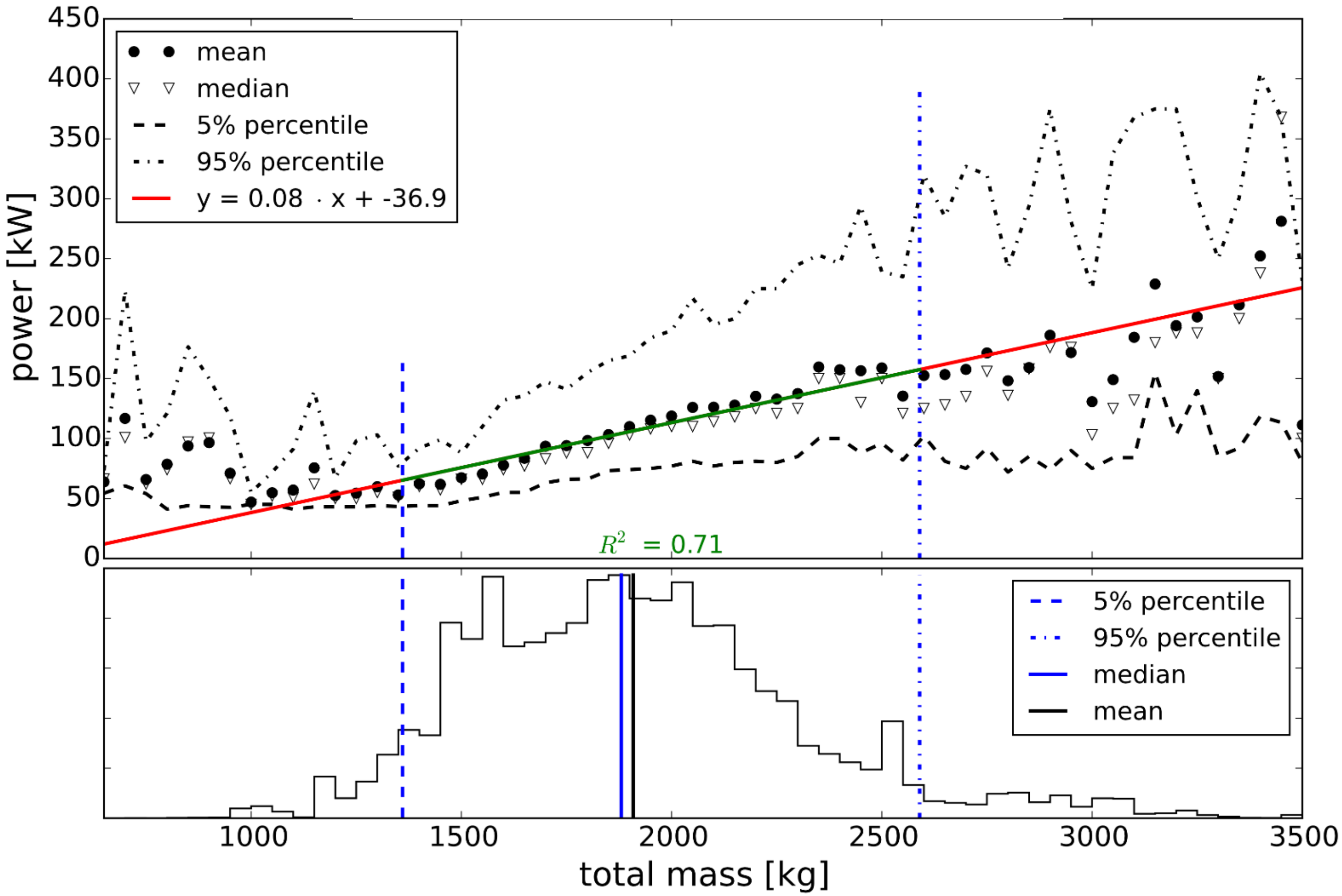
- Implemented framework for «Strategic Guidance»
  - Necessary data-sets gathered
  - Performed "scaling to national level" for passenger car fleet
  - Modeled interventions on that fleet
    → presentation: Aug. 27, 9:35, "Strategic Goals of SCCER Mobility 2017-2020"
  - Began cataloguing interventions within SCCER using online survey
- Vehicle modeling:
  - Refined ICE models → robust representation of part-load behavior
  - Technical specifications of the vehicle fleet → passenger cars
- Next steps:
  - Inclusion of other transport modes and vehicle types
  - Inclusion of electrified propulsion systems

# Highlights: strategic guidance framework
## → combining the mobility demand with technical vehicle models



# Highlights: extension to the whole fleet

## → example: specification of passenger cars




data source: ASTRA MOFIS, own calculations

# B2.4 Main activities

## Research questions

- Which main trends determine current and might determine future mobility in Switzerland?
- How can Swiss mobility be transformed at a macro-level, meso-level and micro-level in order to reach an energy transition?

## Approach

**Trend analysis**

- Trends in mobility
- Economic trends
- Socio-economic trends
- Land-use trends
- Environmental trends
- Socio-cultural trends
- Trends in accessibility and transport infrastructure
- Technological trends

**Transformation of mobility**

- Travel behaviour and behavioural change of individuals
- Expansion of new behaviours
- Case studies

**Swiss potential for transformation of mobility**

Legend: SUPSI | ZHAW | ZHAW work in progress

# Travel behaviour change

First results

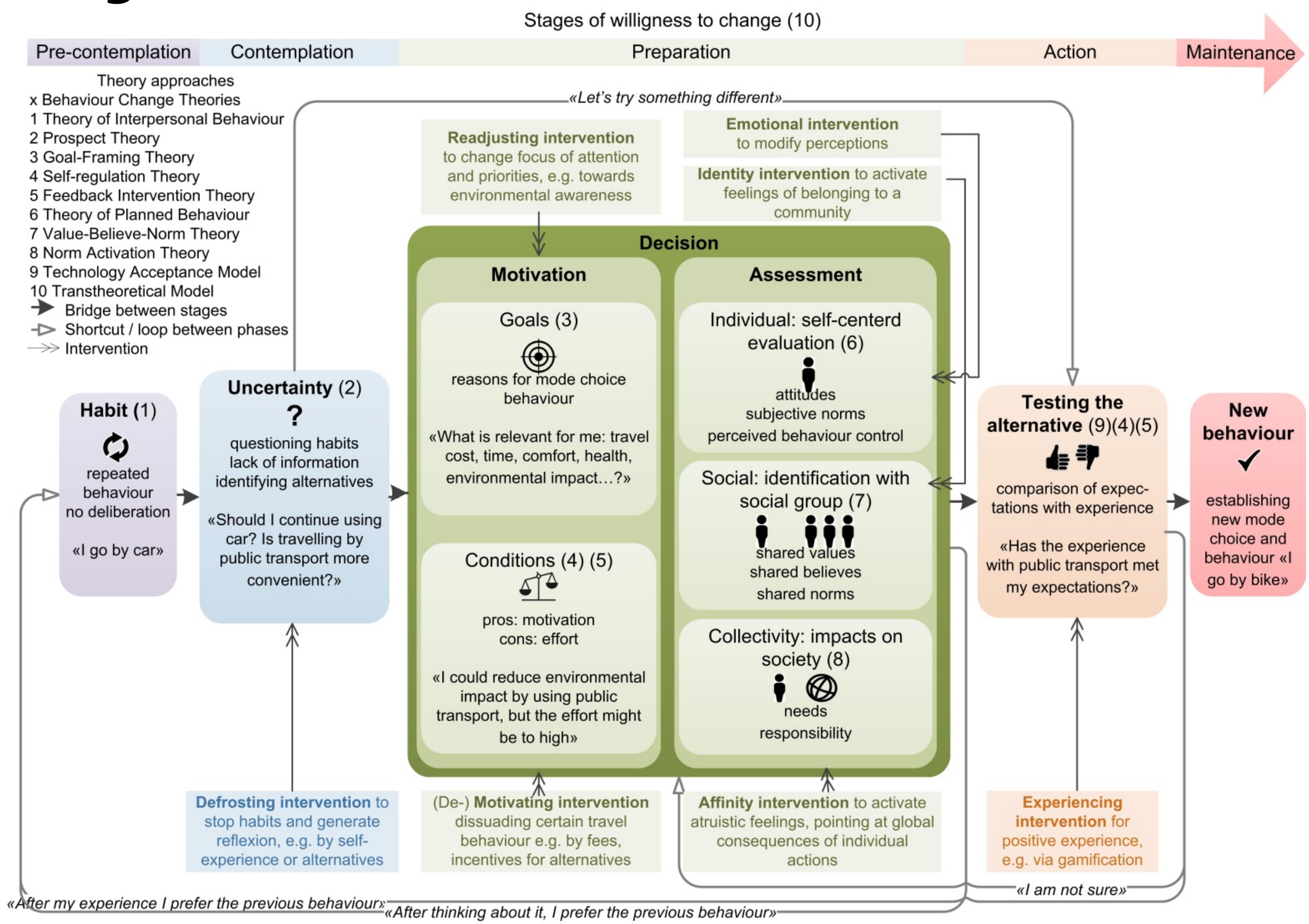
- Integrated model
- Behaviour change
- Theory based

To be done

⇒ Interventions, per

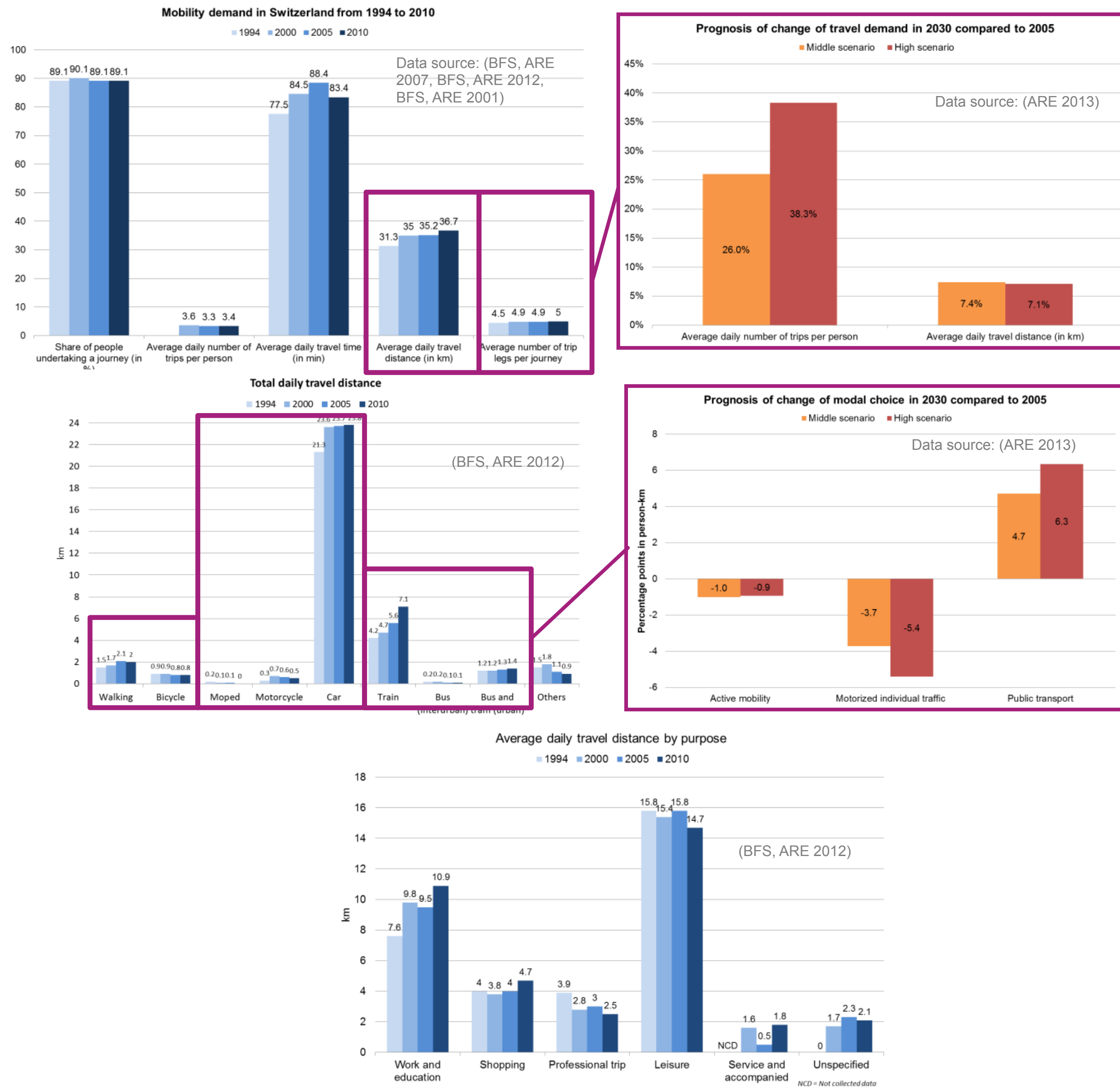
⇒ Stage of change

⇒ Link to other WPs



# Highlight examples

- Trends in mobility
  - Increase of the number of trips and daily travel distance; travel time might remain stable due to better accessibility
  - Longer total distance by train; slight increase in distances by car
  - Longer distance for commuting and shopping; shorter for leisure



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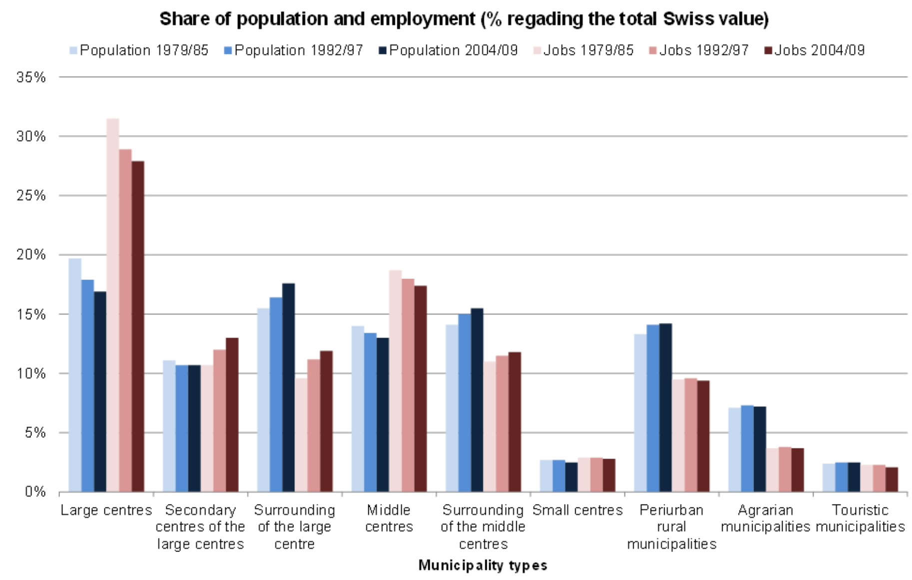
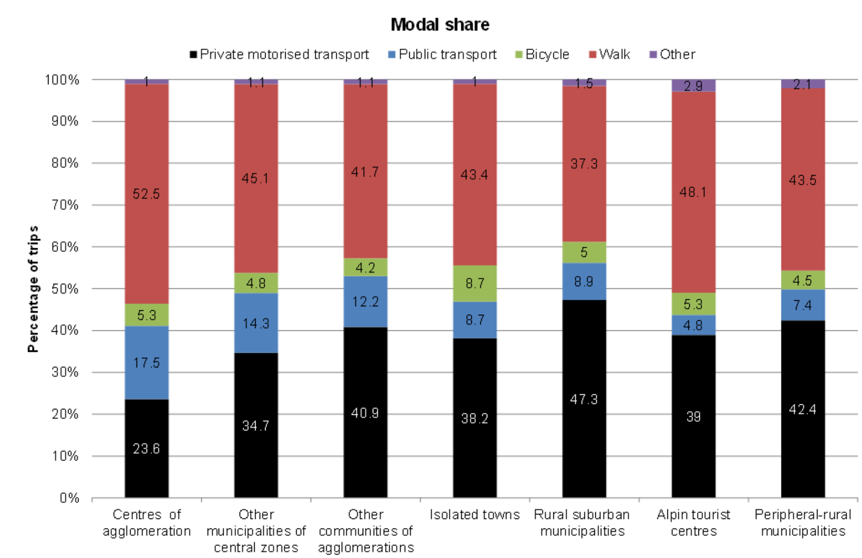
# Highlight examples

- Land use trends
  - Decrease of population and employment in large and middle centres; increase in suburban areas
    - Delocalised mobility demand
    - Higher car use
    - Higher mobility demand




| | | Centre municipalities | Agglomerations | Rural municipalities |
|---|---|---|---|---|
| Daily travel distances (km) | 2000 | 31,8 | 39,8 | 41,2 |
| | 2005 | 31,9 | 37,4 | 38,4 |
| | 2010 | 33,0 | 36,5 | 41,2 |
| Daily travel time (min) | 2000 | 91,2 | 95,9 | 93,3 |
| | 2005 | 93,3 | 91,6 | 89,0 |
| | 2010 | 98,5 | 92,1 | 102,4 |
| Daily number of journeys (num) | 2000 | 3,5 | 3,6 | 3,7 |
| | 2005 | 3,5 | 3,5 | 3,3 |

# CA B2 – Overview of SUPSI activities

Task B2.4.2:
"Analysis of the **mobility system** with regard to the **transformation process** including **living labs** and **stakeholder involvement**"

- Four "living lab" case studies
  - Insights on the opportunities and barriers for behaviour change at the individual level
  - Policy recommendations for future mobility scenarios
  - Interdisciplinary approach, combining social sciences, transport and ICT competences

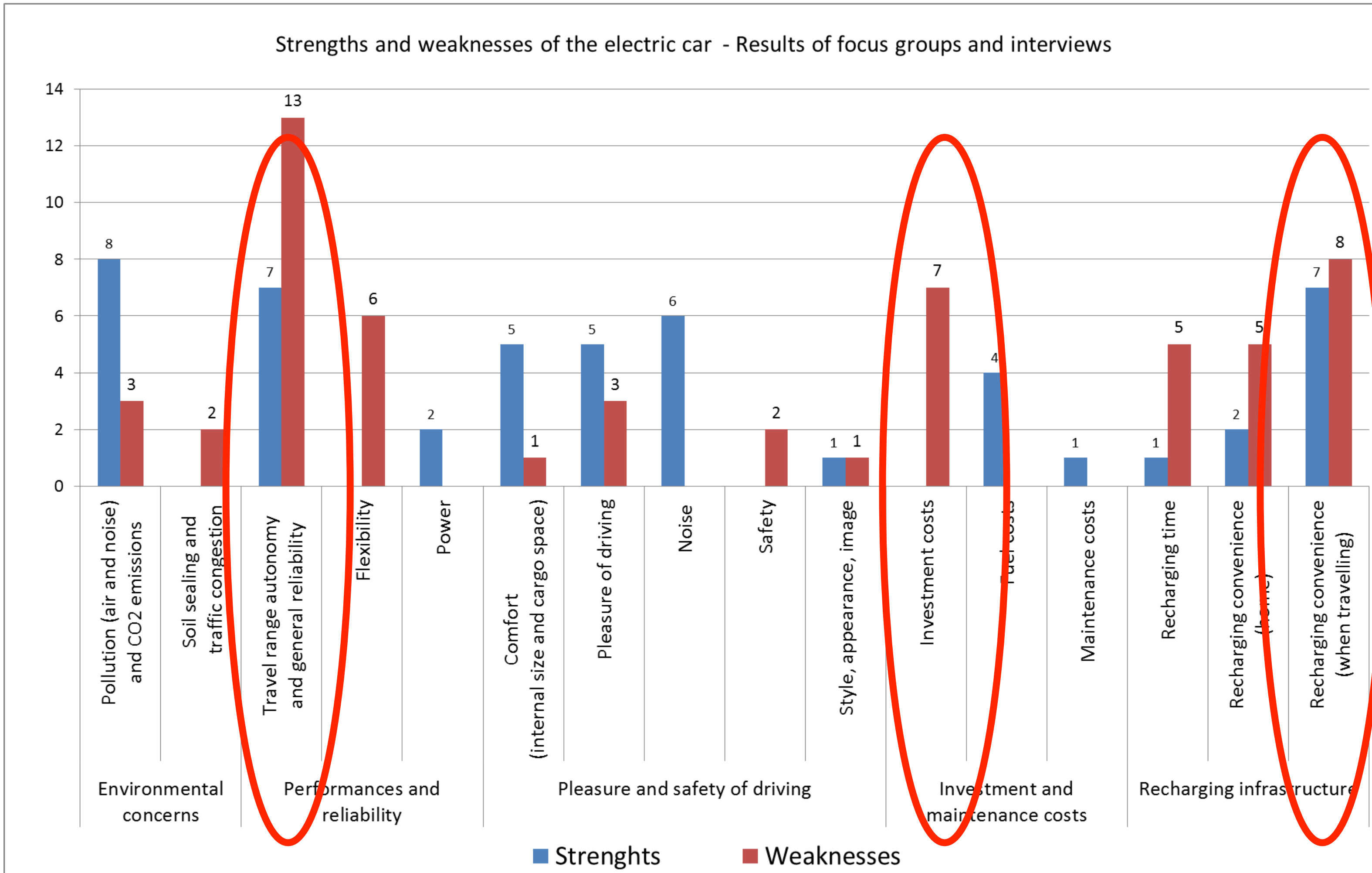
| | | | |
|---|---|---|---|
| Just concluded | **e-mobiliTI** | Potentials for the diffusion of electric vehicles and for a wider transformation of individual mobility patterns. | e-mobiliTI |
| Ongoing | **GoEco!** [in cooperation with CAB1 ETHZ/IKG] | Reduction in the use of the individual car. Use of mobility tracking algorithms and gamification techniques, within a smartphone application. | GoEco! A COMMUNITY BASED ECO-FEEDBACK APPROACH TO PROMOTE SUSTAINABLE PERSONAL MOBILITY STYLES |
| Ongoing | **MOBALT MOBility ALTernatives** | Reduction in the use of the individual car when commuting to work. Use of a smartphone application stimulating social interactions. | mobalt mobilità alternativa |
| Just kicked-off | **Social Car** | Dynamic carpooling in urban areas. Pilot study and assessment of the effectiveness and barriers of the system. | socialcar |

# CA B2 – SUPSI Highlights: results of the e-mobiliTI project 1

**1. Can electric vehicles be used in everyday life, without causing sacrifices or a decrease in personal wellbeing?**

- Performances of electric cars are highly appreciated and they are regarded as a valuable alternative to ICE cars
- However…should they replace their ICE car today, the majority of the participants (10 families in the Lugano area) would not buy an electric car as one and only family car
  - only one family our of ten would buy an electric car as first and only family car
  - six families out of ten would buy an electric car, but only as second (or third!) family car
  - five families out of ten would prefer buying an hybrid electric car (fossil fuel and electricity)
- The main perceived limitation is the automony range: participants dislike the idea they will not be able to use their own car – by the way paid a lot of money! - even though this will only happen for occasional trips

# CA B2 – SUPSI Highlights: results of the e-mobiliTI project 2

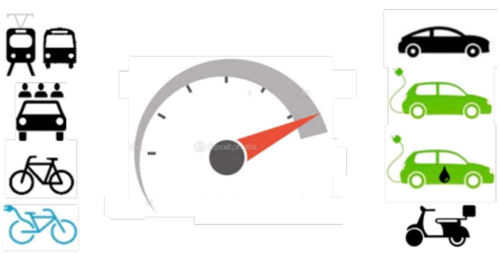


# CA B2 – SUPSI Highlights: results of the e-mobiliTI project 3

## 2. Does the availability of an electric vehicle …

| imply the **pure substitution** of Internal Combustion Engine (ICE) vehicles? | act as a leverage for a **wider transformation** of the mobility styles? |
|---|---|

- The substitution can effectively take place. However, a rebound effect might be produced: in some cases increase in the use of private motorized transport (PMT) is registered
- Instead, no transition is observed:
  - even when combined with electric bicycles, car and bike-sharing, public transport cannot compete with cars (either ICE or electric): when a PMT means of transport is available, it markedly prevails over other mobility options
  - a decrease in PMT would require further improvements in the quality of the mobility options other than the car, especially in terms of flexibility, capillarity, comfort and safety



# Capacity Area B2

THELMA

# Selected highlight:
## Inter-disciplinary assessment of current and future car options

Stefan Hirschberg et al.

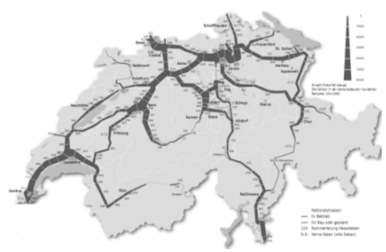
# THELMA (Technology Centered Electric Mobility Assessment)

- Understanding the multi-criteria implications of wide-spread electric vehicle use in Switzerland

THELMA

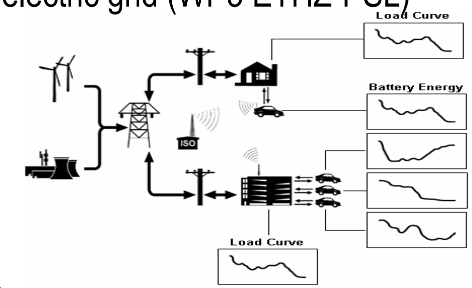
## Transportation System

Traffic simulation, case studies (WP4 ETHZ-IVT/ETHZ-ESD)



## Power System Modeling

Role of and requirements on the electric grid (WP3 ETHZ-PSL)



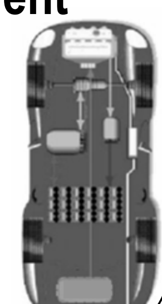

## Technology Assessment

**Life Cycle Assessment**

LCA-based environmental performance (WP1 EMPA/PSI)

**Vehicle Simulation and Powertrain Assesment**

(WP2 ETHZ-LAV/PSI-LEA)



## Analysis Integration

Cost-benefit analysis of electric mobility options on technology and fleet level, Relative sustainability of technology options (WP5 PSI-LEA)

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Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

EMPA

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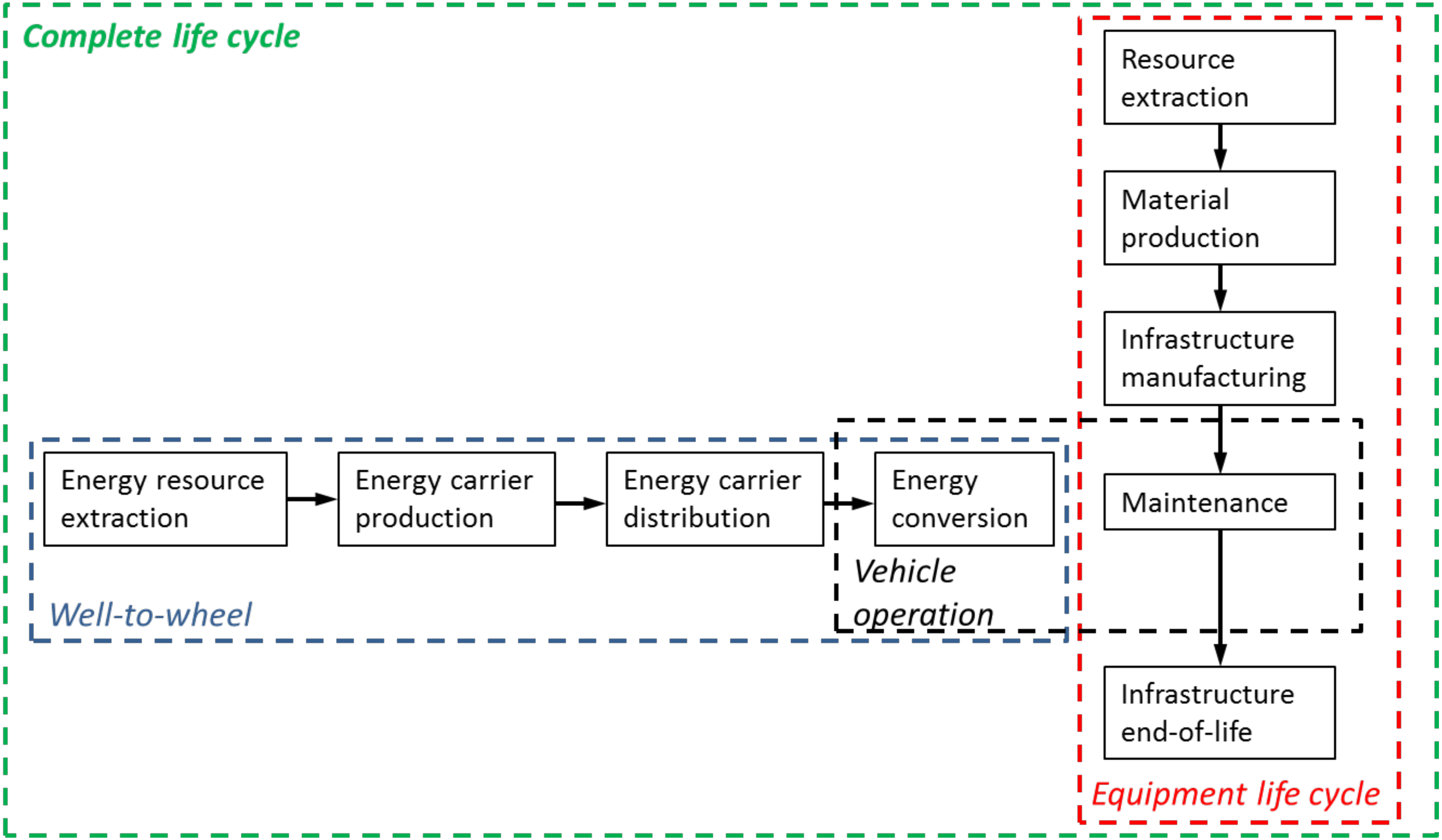
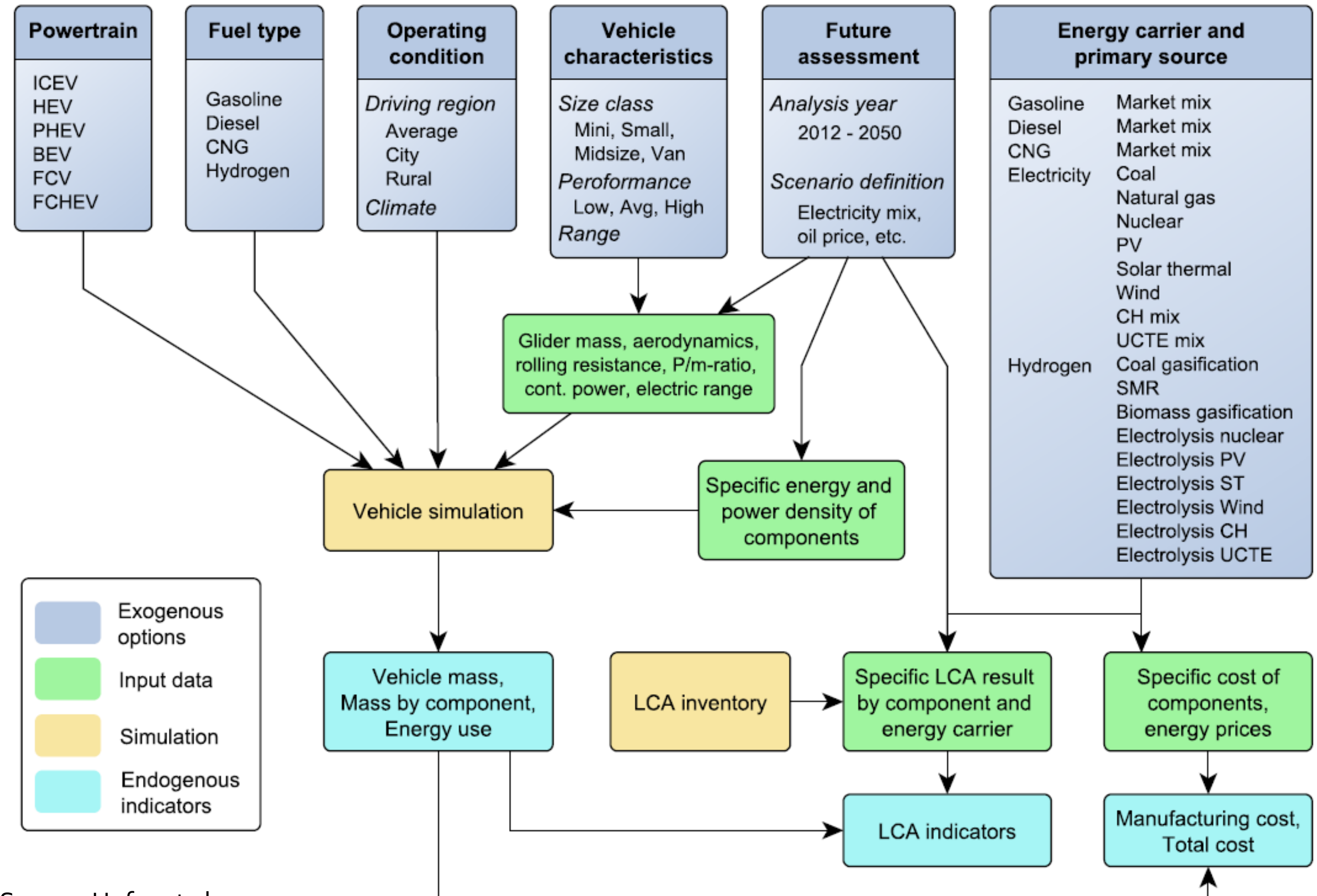
# Scope of Life Cycle Assessment

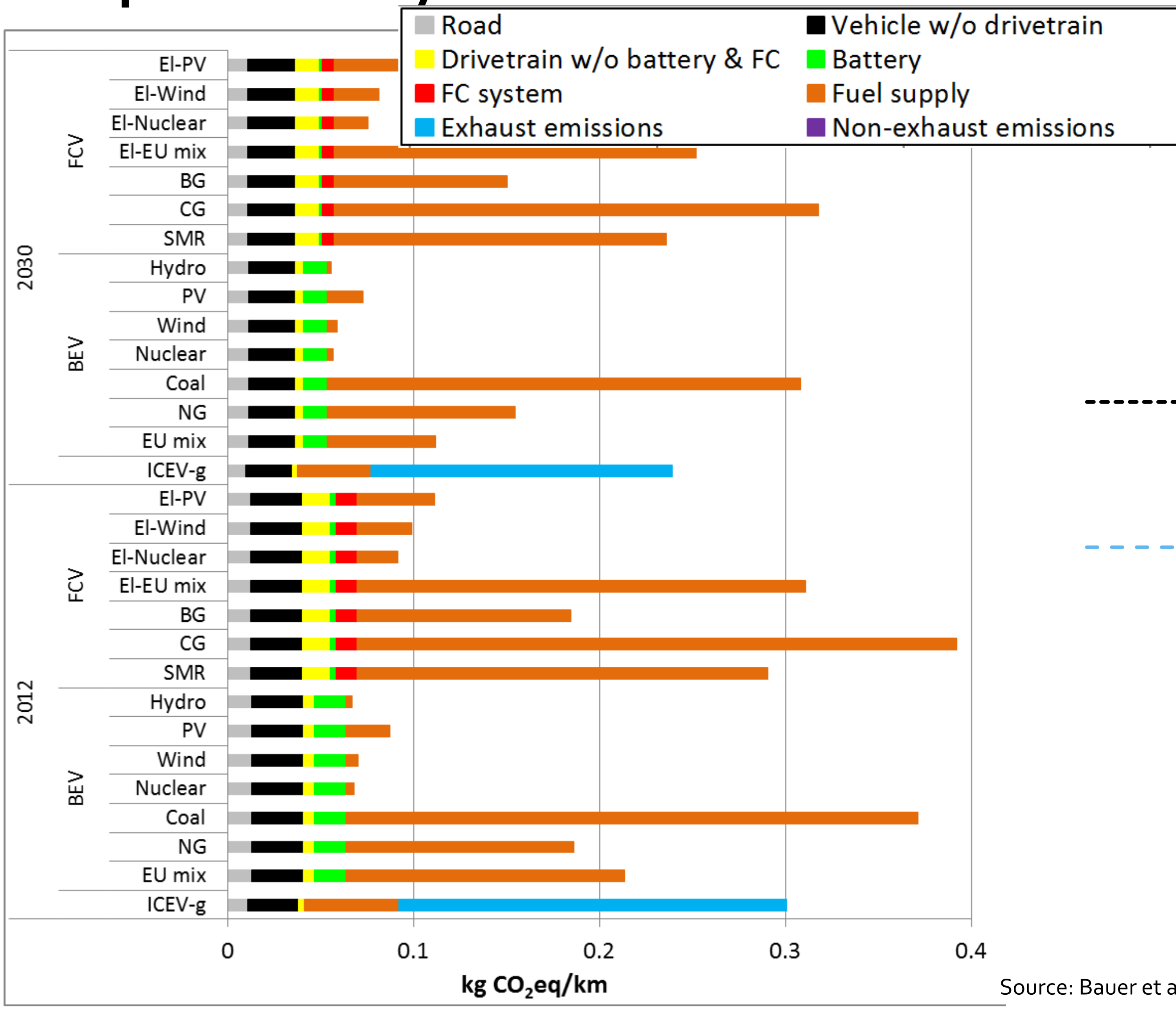


# Multi-Indicator Analysis Tool Framework




Source: Hofer et al., 2014

# Complete Life Cycle GHG Emissions: Midsize car 2012-2030




Gasoline reference 2012

Gasoline reference 2030

Source: Bauer et al., 2015

# Multi-Criteria Decision Analysis (MCDA) process

## Subjective & objective elements

Selection of technologies

↓

Selection of indicators for technology assessment

↓

Quantification of indicators for each technology

↓

Normalisation of indicators

↓

Weighting of indicators*

↓

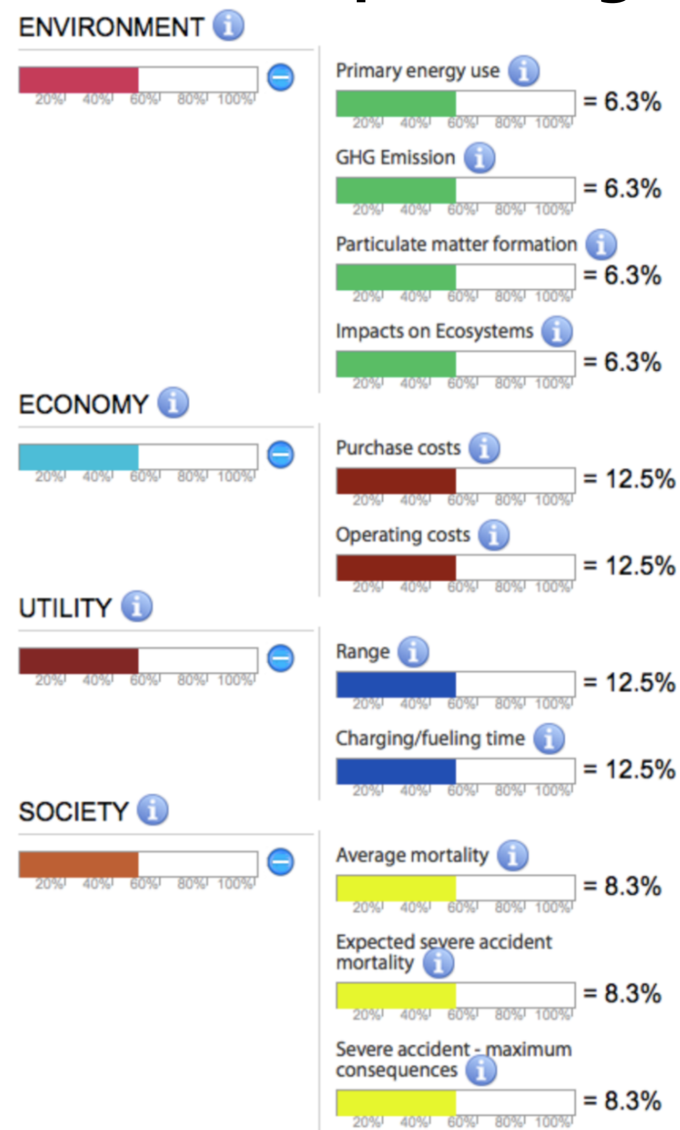
Aggregation: Combination of indicator values & weighting factors

↓

Calculation of the sustainability index
= ranking of technologies

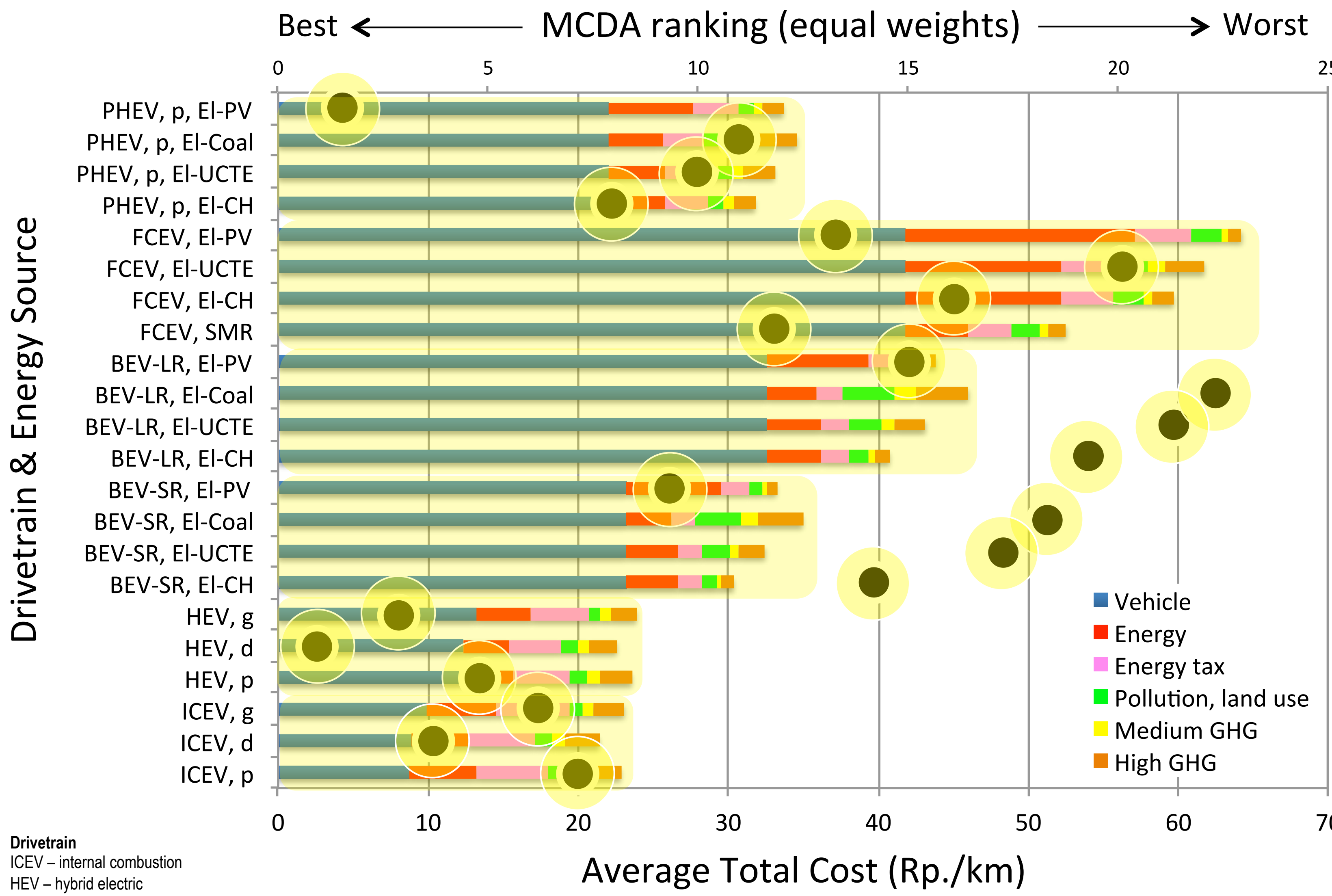
* supported/carried out by web-based „surveys“

# MCDA Criteria Structure: Equal weights




Source: Hirschberg et al., to be published

# Performance of lower mid class cars (2012)




**Drivetrain**
ICEV – internal combustion
HEV – hybrid electric
BEV-SR – battery electric (short range)
BEV – electric vehicle
FCEV – fuel cell electric
PHEV – plugin hybrid

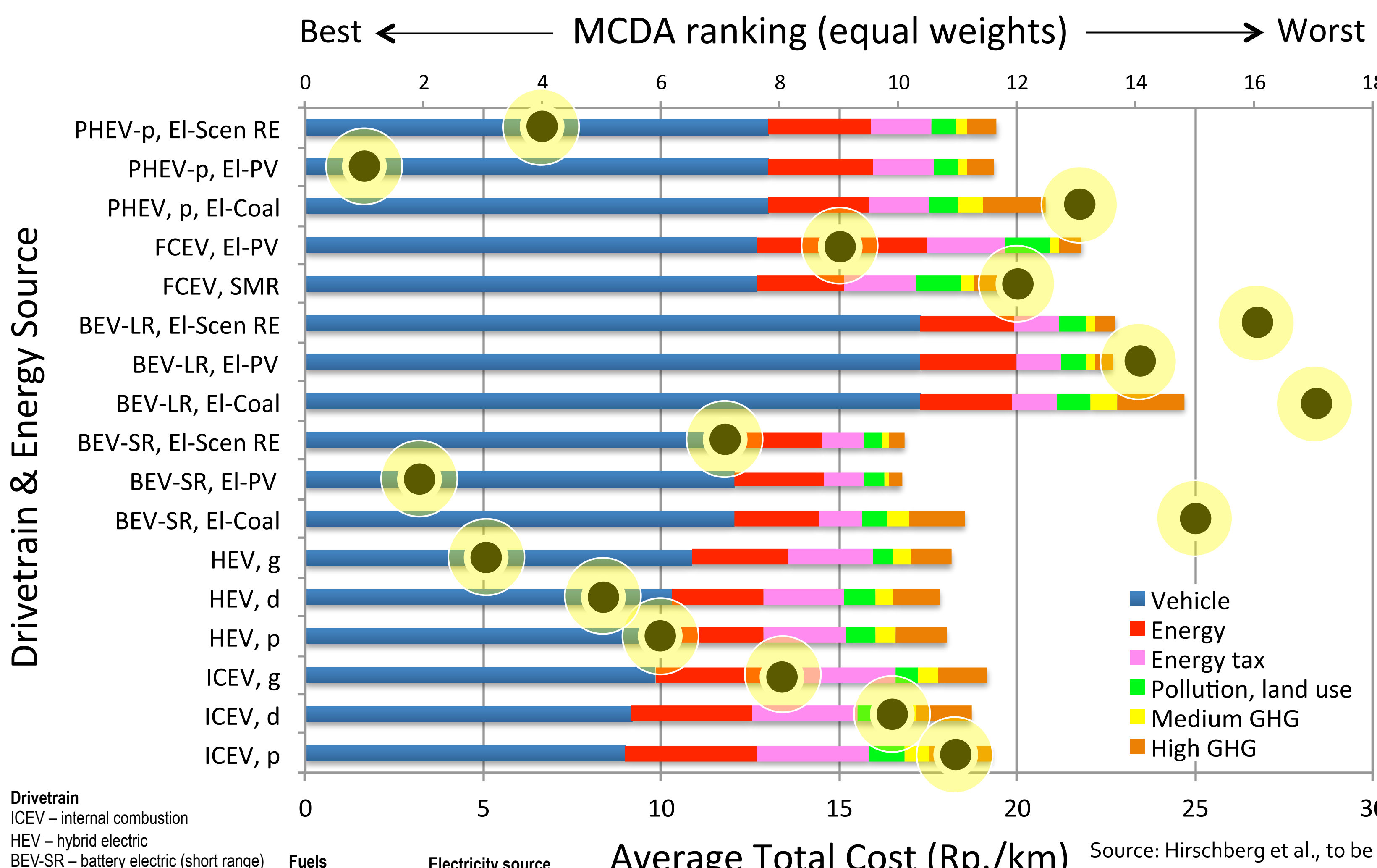
**Fuels**
p – petrol
d – diesel
g – gas (CNG)

**Electricity source**
CH – Swiss electricity mix
UCTE – import mix
(Coal, Wind, PV, Hydro as shown)

**Hydrogen source**
SMR– steam methane reforming
El – electrolysis (see left)

Source: Hirschberg et al., to be published

# Performance of lower mid class cars (2050)




Source: Hirschberg et al., to be published

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**Hydrogen source**
SMR– steam methane reforming
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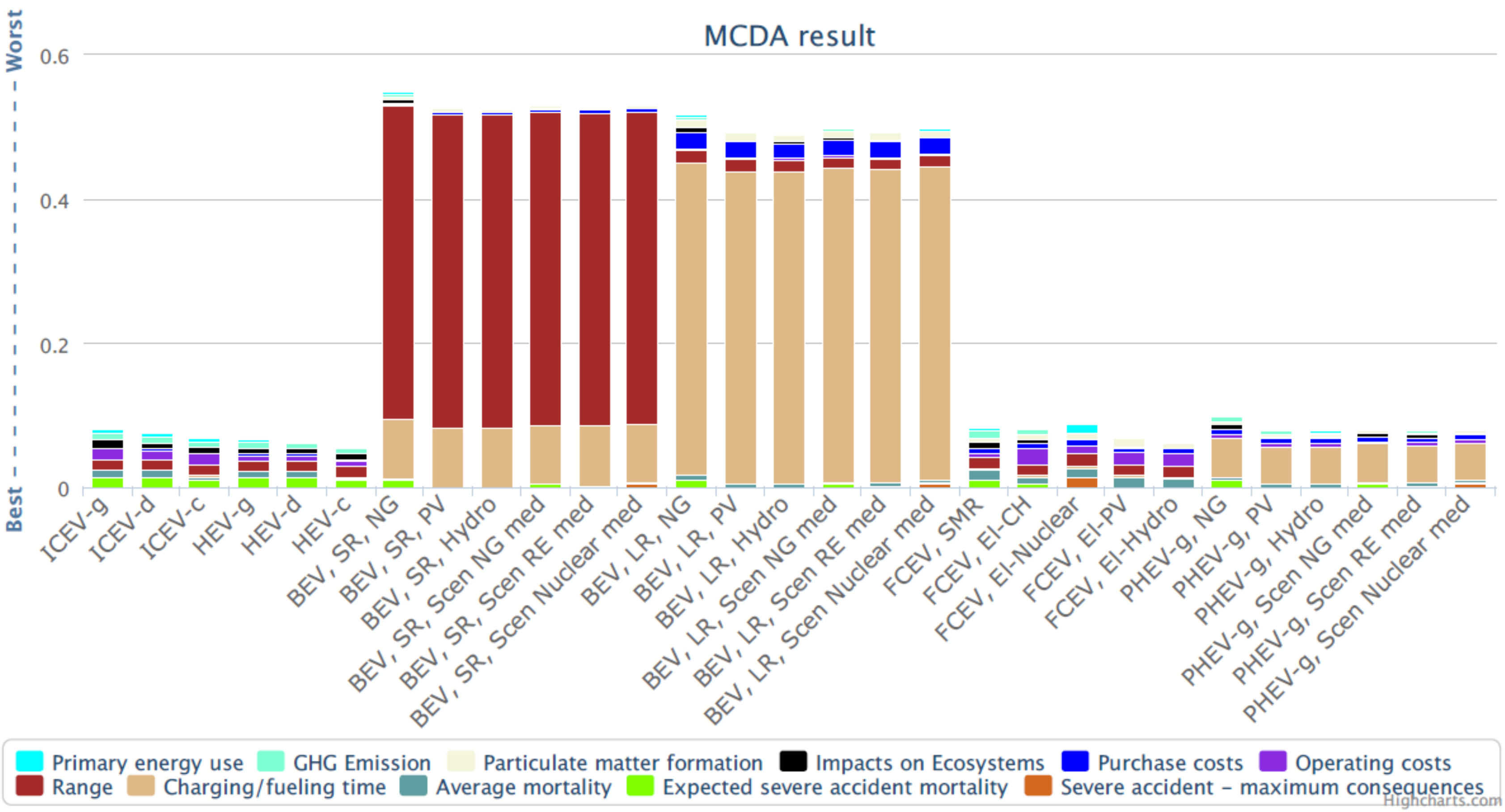
# MCDA: Utility focus, midsize car 2050




Source: Hirschberg et al., to be published

# Preliminary conclusions on electric mobility

- Electric mobility can reduce energy consumption and GHG-emissions if non-fossil energy resources are used for electricity and hydrogen production.
- Electric mobility faces challenges with regard to costs, range, overall environmental performance, infrastructure and remarkable improvements of conventional technologies.
- Environmental external costs of individual technologies with high standards have limited influence on their ranking but cumulative external costs are very substantial.
- Future BEVs and FCEVs exhibit strongly improved performance over a range of criteria and stakeholder profiles.
- The cost and utility differences between short and long range BEVs can have significant effects on their attractiveness and market penetration.
- Ongoing B2 research extends the developed frameworks to all mobility modes including modeling of the overall transport system.

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# CA B2 Posters & Acknowledgements

- Brian Cox and Chris Mutel (PSI-LEA)
  "Environmental and Cost Assessment of Motorcycles"
- Brian Cox, Wojciech Jemiolo and Chris Mutel (PSI-LEA)
  "Environmental Assessment of Airplanes"
- Rashid Waraich and Kannan Ramachandran (PSI-LEA)
  "Energy Economic Modeling of the Swiss Transport Sector"
- Lukas Küng and Gil Georges (ETHZ-LAV)
  "Strategic Guidance Project: an overview"
- Merja Hoppe, Alberto Castro (ZHAW)
  "Transformation of Mobility. Context Perspective"
- Roman Rudel, Francesca Cellina, Albedo Bettini (SUPSI-ISAAC)
  "e-mobiliTI - Potentials and implications of the transition to electric mobility. Insights from a living lab in Southern Switzerland"
- Francesca Cellina, Vanessa de Luca, Nikolett Kovacs, Andrea E. Rizzoli, Roman Rudel (SUPSI-ISAAC) & Dominik Bucher, Paul Weiser, Martin Raubal (ETHZ-IKG)
  "*GoEco!* A smartphone application leveraging eco-feedback and gamification techniques to nudge sustainable personal mobility styles" (together with CA B1)