Capacity Area B2:
Integrated Assessment of Mobility Systems

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Integrated Assessment of Mobility Systems (CA B2)

Methods and Tools:

Motivation – Swiss Energy Strategy 2050

- Fuel Switching
- Hybridization
- Fuel Cells
- Lightweighting
- Modal Shift
- Electrification
- Aerodynamics
- Increased Efficiency

Percent of 2010 Values

Data Source: Prognos 2012
Methodology
LCA & Costs of Transport Technologies - Results Examples

Motorcycle Climate Change Impacts

- ICEV 11-40kW 2050
- ICEV 11-40kW 2015
- ICEV 11-40kW 1990
- FCEV 11-40kW 2050
- FCEV 11-40kW 2015
- BEV 11-40kW 2050
- BEV 11-40kW 2015

Costs of Freight Transport

Airplane Fuel Consumption

Material Composition of Aircraft
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 CO2/primary energy reduction
  - **Means**: energy/CO2 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
  - 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**
  - 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

Data source: (BFS, ARE 2007, BFS, ARE 2012, BFS, ARE 2001)

Data source: (ARE 2013)
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

<table>
<thead>
<tr>
<th>Centre municipalities</th>
<th>Agglomerations</th>
<th>Rural municipalities</th>
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<tr>
<td>2000</td>
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<td>2005</td>
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<tr>
<td>2010</td>
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<td>Daily travel distances (km)</td>
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<tr>
<td>Centre municipalities</td>
<td>2000</td>
<td>3.5</td>
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<tr>
<td>2005</td>
<td>3.5</td>
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Share of population and employment (% regarding the total Swiss value)

- Population 1978/85
- Population 1992/97
- Employment 2004/09
- Jobs 1978/85
- Jobs 1992/97
- Jobs 2004/09

Modal share

- Private motorised transport
- Public transport
- Bicycle
- Walk
- Other

Percentage of trips
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

<table>
<thead>
<tr>
<th>Just concluded</th>
<th>e-mobiliTI</th>
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<tbody>
<tr>
<td></td>
<td>Potentials for the diffusion of electric vehicles and for a wider transformation of individual mobility patterns.</td>
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<tr>
<th>Ongoing</th>
<th>GoEco! [in cooperation with CAB1 ETHZ/IKG]</th>
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<tbody>
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<td>Reduction in the use of the individual car. Use of mobility tracking algorithms and gamification techniques, within a smartphone application.</td>
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<th>MOBALT MOBility ALTeratives</th>
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<td>Reduction in the use of the individual car when commuting to work. Use of a smartphone application stimulating social interactions.</td>
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<tr>
<th>Just kicked-off</th>
<th>Social Car</th>
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<td></td>
<td>Dynamic carpooling in urban areas. Pilot study and assessment of the effectiveness and barriers of the system.</td>
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</table>
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 out 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 autonomy 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
CA B2 – SUPSI Highlights: results of the e-mobiliTI project

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

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

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THELMA (Technology Centered Electric Mobility Assessment)

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

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 Assessment (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)
Scope of Life Cycle Assessment

**Complete life cycle**

- Energy resource extraction
- Energy carrier production
- Energy carrier distribution
- Energy conversion
- Infrastructure manufacturing
- Maintenance
- Infrastructure end-of-life

**Well-to-wheel**

**Equipment life cycle**

- Resource extraction
- Material production
Multi-Indicator Analysis Tool Framework

Source: Hofer et al., 2014
Complete Life Cycle GHG Emissions: Midsize car 2012-2030

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<th>Year</th>
<th>Fuel Type</th>
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<th>2030</th>
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<tr>
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<td></td>
<td>Vehicle w/o drivetrain</td>
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<td></td>
<td>Drivetrain w/o battery &amp; FC</td>
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<td>FC system</td>
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<td></td>
<td>Battery</td>
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<td></td>
<td>Fuel supply</td>
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<td></td>
<td>Non-exhaust emissions</td>
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Source: Bauer et al., 2015

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**Gasoline reference 2012**

**Gasoline reference 2030**
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)

Best → MCDA ranking (equal weights) → Worst

Average Total Cost (Rp./km)

Drivetrain & Energy Source

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)

Average Total Cost (Rp./km)

Source: Hirschberg et al., to be published
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.
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)