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Mobility Research and Innovation in Switzerland

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Book of Abstracts

1 Invited Lectures & Keynotes

Mobility & Energy: Past – Future

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The megatrend of mobility is naturally linked to energy. Whether we are travelling on foot, using a bicycle, taking the train or getting into a car: energy is needed anywhere. Due to the laws of physics, it is what makes movement possible. Without energy, there is no mobility and no traffic. In times of climate change and discussions about sustainability, energy has become a crucial issue for the future, at least since Fukushima. Transport is responsible for more than one third of Switzerland's CO_2 emissions. The economy and the professional world, spatial planning, housing, food and leisure are also affected by the energy transition. Now it is time to act. There is often a lack of knowledge of the complex interrelationships and their effects on society. The Swiss Museum of Transport links mobility with technology, the environment and society and aims to become a central platform for the topic of energy with a new permanent focus. In this platform, we are planning to include educational elements such as experimental learning and laboratory testing sites.

In doing so, the Swiss Museum of Transport would like to work together with partners from the energy sector. Switzerland's most visited museum sees itself as a partner in the transformation process towards net-zero climate neutrality in 2050 (CH strategy).

Future mobility and the CSFM at ETH Zürich

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ETH is setting up a new competence centre to pool its resources addressing the challenges of the mobility of the future. The talk will introduce it. Using the experience of the COVID19 pandemic, it will reflect the challenges and dilemmas.

Beyond the Swiss transport outlook 2040

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The Federal Office for Spatial Development ARE regularly joins forces with other federal agencies – including the Federal Office of Transport FOT, the Federal Roads Office FEDRO, the Swiss Federal Office of Energy SFOE and the Federal Office for the Environment FOEN – to develop and simulate scenarios for passenger and freight transport. These scenarios serve as a basis for planning road and rail infrastructure, for policy decisions in the mobility and planning sectors as well as inputs for the Energy Outlook, noise and air emission projections. The 2016 published transport outlook 2040 is today the valid basis.[1]

Since then the ARE has developed a new passenger transport model (NPVM)[2] with 8000 traffic zones and updated the freight transport model (AMG)[3] and the land use model (FALC)[4]. In combination, these models are applied to calculate the transport outlook 2050. 2017 serves as base year, official demographic and economic projections are used as inputs. The four if-then scenarios depict future mobility along different assumptions with respect to the number of trips per person and day, the degree of urbanisation, mobility prices, transport costs and the availability of mobility tools. Results will be presented to the public in November 2021. All assumptions, data and results (graphs, EXCEL-Sheets, Shapefiles, VISUM-Versions) are documented and will be available online.

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[3] Nationale Güterverkehrsmodellierung (admin.ch)

[4] Flächennutzungsmodellierung (admin.ch)

Regulatory framework in Switzerland and the European Union

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In average years, transport is responsible for almost 40% of energy consumption and greenhouse gas emissions in Switzerland. Over three quarters of these emissions are caused by motorised road traffic. The most important incentives for a transformation towards energy-efficient and climate-friendly mobility are the CO2 emission regulations, which in Switzerland have so far been based on the regulations in the EU. With the rejection of the CO2 law in the referendum of 13 June 2021, the targets in Switzerland are frozen at the level of 2020 (95 g CO2 according to NEDC or 118 g CO2/km according to WLTP). In the EU, however, the European Commission has put forward more ambitious targets for cars and vans for discussion as part of the "Fit for 55" package. The goal is to reduce CO2 emissions by 55% by 2030 compared to 1990. Furthermore, the European Commission proposes a phase-out date for vehicles with internal combustion engines. From 2035, only emission-free vehicles may be newly registered. Surprisingly, there was no outcry from the automotive industry. Many OEMs have themselves defined targets that are almost more ambitious for phasing out the internal combustion engine. It is open now how Swiss regulation will develop in the long-term. However, since Switzerland imports a large part of its vehicles from the European region, the regulations there will also have an impact on Switzerland.

Pathways to a Net-Zero CO_2 Swiss Mobility

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The Paris Agreement on Climate Change as well as the Swiss Energy Strategy 2050 and the strategic intention of the Swiss Federal Council to achieve net zero greenhouse gas (GHG) emissions by 2050 pose grand challenges for both the global and national energy systems.

In Switzerland, mobility accounts for about 40% of the domestic GHG emissions and 48% of the carbon dioxide (CO_2) emissions. Domestic GHG emissions consist of about 99% CO_2, therefore we use CO_2 as lead indicator in this document but refer to GHG emissions when results of life cycle assessment (LCA) are discussed.

The present White Paper examines pathways to a sustainable future of the mobility sector from a systems point of view. Recognizing the profound importance of transportation for the Swiss economy, the multitude of its environmental impacts beyond climate change and the strategic relevance of energy supply security, we focus primarily on CO_2 emissions as an indicator for sustainability and on the overarching need to reach net zero CO_2 output by the middle of the century. In doing so, we consider worldwide and in particular European developments as Switzerland is embedded in the international economic, energy and transport environment with regard to technological, market related and increasingly legislative aspects.

Our analysis starts with a description of the current state of affairs of the Swiss mobility sector and the developments during the last 30 years in order to shed light on the major drivers for its evolution. Despite the widespread public perception that mobility-related politics have failed to deliver positive trends in the direction of decarbonization, our data show positive signs of saturation and a gradual decline of CO_2 emissions. Considering that the population of the country has increased by 27% and GDP per capita by 23% from 1990 to 2018, we find that technology-related efficiency measures and support for public transportation bear fruit already. This, however, is not the case for the aviation sector, for which the rapid rise in demand has led to an increase of CO_2 emissions by more than 50% within the same period. Overall, despite first encouraging signs, we recognize that these are by far insufficient in view of the strict and ambitious national climate targets.

Therefore, we argue that a massive acceleration of CO_2 reduction efforts must be initiated and maintained over the next decades. To assess and prioritize promising steps in this direction we use an analysis framework along the following routes:

- **Avoid** excessive transport demand
- **Shift** to more efficient and environmentally compatible modes
- **Improve** energy conversion efficiency along the full conversion chain from primary to useful energy
- **Replace** fossil energy carriers with new ones exhibiting net zero CO_2 emissions through direct or indirect electrification

Although such a vector of directions is widely recognized, it is necessary to examine limitations, cross-influences among the individual components and the specificity of individual transport sectors. Thus, we attempt to consider such effects and overlay the above strategic thrusts with an examination of passenger and freight, short-, mid- and long-haul modes, surface, and road transport as well as aviation and shipping.

We show that the above four routes can be facilitated by policy, pricing, consideration of behavioural aspects and appropriate use of digitalization. Furthermore, a strong commitment for the support of public and – for the urban environment – low-speed modes for passenger transport as well as consistent spatial planning in the long term will be crucial. We also point to the potential rebound effects due to lower costs of more efficient transport means (incl. digital technologies) and argue for a clear strategy to address them. Furthermore, avoid and shift potentials for long-haul transport are rather limited (with the exception of high-speed rail as a substitute for short- and medium-haul aviation).

Improving energy conversion efficiency (propulsion systems and vehicle design) has ample potentials both for passenger and freight transport and the corresponding low-hanging fruits need to be reaped to the fullest extent possible. However, it is important to notice that commercially dominated transport modes (heavy-duty freight on the road, shipping, and aviation) already take advantage of efficiency improvements, simply because in their case fuel expenditures constitute a major part of the total cost of ownership (TCO). Also, the improve trajectory must rely on both technology innovation and policy instruments for guiding consumer and investor decisions.

Ultimately, the replace strategy component will be necessary to achieve full decarbonization. Though the other three components will be indispensable to avoid exceeding the CO_2 budget to limit global warming to 1.5 –2°C, only the wide use of non-fossil energy carriers will lead to net zero emissions around 2050.

When examining the individual mobility sectors, it is conceivable that direct electrification with batteries will be more appropriate for short- to mid-range applications, while chemical energy carriers (hydrogen, H_2, and synthetic fuels) will contribute decisively to the decarbonization of mid- to long-range sectors. Though this insight is widely accepted, in this White Paper we present some additional, in part non-intuitive results, namely:

- LCA for cars and trucks indicates that CO_2 emissions depend much stronger on the primary energy used than on the propulsion technology. Furthermore, near zero CO_2 emissions from the mobility sector can only be achieved, if the industrial manufacturing sector is decarbonized in parallel, because the embedded emissions (infrastructure, vehicles, etc.) constitute a major part of the CO_2 output, when the energy carriers are almost CO_2 free.
- Considering external costs and technology progress, our analysis shows that TCO of the car fleet will remain about the same as today in the net zero GHG emissions scenario. The share of external to total ownership cost will thereby decrease from the current one third to about 15% in 2050.
- A detailed techno-economic optimization shows that in the long-term net zero CO_2 for the passenger car sector can be achieved at the lowest cost with a wide portfolio of energy carriers (electricity, hydrogen and synthetic fuels) and powertrain technologies (battery electric, plug-in hybrids and fuel cells). This contrasts with emerging policies favouring battery electric vehicles (BEV) almost exclusively.
- Concerning national strategies for the supply of energy carriers for the decarbonization of mobility, we argue that a mix of domestically produced electricity with a portfolio of renewable synthetic fuels, mainly produced abroad, will probably be the most appropriate means for achieving net zero CO_2. The reasons for sourcing such fuels from outside Switzerland are manifold:
    - The additional electricity demand for decarbonizing transport through electrification amounts to about one third of the current electricity demand of the country excluding aviation and it exceeds this current demand when the production of aviation fuels is included.
    - The need for electrification of other energy sectors (industry, buildings, and heat) together with the gradual phasing out of nuclear power plants.
    - The fact that there are many potential locations worldwide where synthetic fuels can be produced at massively lower costs using solar and on-/off-shore wind power and transported with existing infrastructure. This is in contrast to the limited and expensive options for transporting large amounts of electricity over long (even intercontinental) distances.

Furthermore, we point to an often-overlooked issue, namely the transitional dynamics towards a sustainable mobility system within only a few decades. Since the lifetime of key assets in the transportation sector amounts to several decades, it will be crucial to invest in future technologies early enough in order to avoid lock-in effects and minimize stranded assets. In addition, the repurposing and reuse of existing long-lasting infrastructure for new energy carriers will be important to keep costs under control. Finally, using new energy carriers with drop-in capabilities to replace fossil fuels during the lifetime of vehicles, in particular ships and aircraft, will constitute a relevant part of the effort to minimize cumulative CO_2 emissions over the next decades.

Orchestrating the replacement of fossil energy carriers across different mobility sectors will require massive improvements of the electricity grids when BEVs are considered as well as new transport and distribution networks in cases where hydrogen is employed. Well-coordinated worldwide efforts will be crucial for decarbonizing the upstream processes for producing assets (batteries, vehicles and fuel cells) and energy carriers with an overall benign environmental footprint and at affordable costs.

Enabling the transition to sustainability for the global mobility system will require contributions both by technology innovation and by policy design. While technology innovation will be important across the whole chain of readiness levels, policy design will be a complex endeavour that needs to navigate within a set of requirements, namely:

- Internalization of external costs, with emphasis on environmental impacts and with priority on damages related to climate change.
- Balancing and compensating disadvantages for low-income groups to ensure social acceptance.
- In addition to the development of instruments for influencing consumer behaviour (buying and using equipment for short-range passenger transport), emphasis needs to be put on guiding highly important decisions made by investors. Such policy must employ predictable and consistent legislation, because investments towards reshaping the global mobility and energy systems will be required at an unprecedented scale, particularly investments in new infrastructure.
- Concerning national mobility policy, it will be necessary to align regulations and standards with international and particularly European developments.

Overall, our assessment concludes that the transformation of the mobility system towards climate neutrality is a huge challenge. Its successful implementation will require informed decisions, innovative technology and business models, fair pricing, and a combination of strategic coherence with tactical flexibility to address unforeseen developments.

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The Energy Perspectives 2050+

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The Energy Perspectives 2050+ (EP 2050+) analyse in a net-zero emissions scenario (ZERO) how to develop an energy system that is compatible with the long-term climate goal of net-zero greenhouse gas emissions by 2050 and, at the same time, ensures a secure energy supply. The results show, that the goal can be reached with existing or developing technologies but the transition has to be fast in the next thirty years. For the transport sector the share of battery electric vehicles grows rapidly and in the long term, hydrogen, biofuels electricity-based fuels (PtL and PtH2 will play an important role in heavy goods transport. Rail transport can play an important role in reducing energy consumption, CO2 emissions and the demand of PtX and biofuels.However research and innovation, especially social research, is and will be an important part of this transition.

User preferences for smart EV charging

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With the increasing adoption of electric vehicles as a mean to decarbonize the mobility sector, the need and search for moderated charging solutions grows too. Smart charging solutions have the potential to smoothen and shift charging peaks for an improved integration into the electricity market. For the wide spreading of smart charging solutions EV drivers would have to agree to a controlled charging process or react to incentives and adopt their charging behavior accordingly. Consequently, understanding EV drivers' preferences is key to win their consent. This presentation reports from existing research in the field and an empirical study conducted in Switzerland.

Previous research surveyed the broad public or tested very restrictive charging contracts, which unsurprisingly led to low acceptance levels. Our own study sheds a particular light on potential adopters of smart charging solutions by surveying current and future EV drivers. A conjoint study measures to what extent EV drivers are willing to adjust the charging location, duration and charging mode to enable smart charging. The results of analyzing 6'240 individual decisions for charging offers reveal insights relevant for providers of smart charging offers. The findings suggest that EV drivers' are willing to accept smart charging when arising discomforts of increased uncertainty are compensated with upgraded offers for other attributes. Further, we find a sweet home bias among respondents, as they have a disproportional preference for charging at home. Three distinct customer segments can be identified, of which one is particularly suited to be addressed as early adopters. The results of this study are promising to support developing business models that aim to exploit the potential of smart charging.

Sustainable decision-making and mobility behaviour

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The transition towards sustainable transportation requires the active involvement of citizens, including significant behaviour change of individual actions. These actions can be related to investments in more sustainable technology such as electric vehicles or change in mobility behaviour such as increased use of public transport. Insights from the behavioural sciences can increase our understanding of citizens' decisions in the transportation domain and can eventually provide opportunities to promote more sustainable decisions and actions. The talk will provide examples of how an analysis of decisions and the underlying psychological mechanisms can lead to evidence-based low-invasive interventions. Such intervention techniques can serve as an effective complementary policy instrument in addition to or in combination with classic policy interventions. The first example illustrates by means of cross-national representative data from Germany and the U.S. that car drivers significantly underestimate the range coverage potential of electric vehicles. The study moreover shows that correcting these underestimations by providing tailored information can reduce range anxiety and increase the willingness to pay for electric vehicles. The second example goes beyond purchase decisions and examines how providing tailored information can increase the usage of smart charging technology for electric vehicles. The main principle of this technology is that the charging process will be adapted to the generation of renewable energy and lower energy prices. For drivers this means that they can benefit from increased use of renewable energies and/or lower prices, but also have to accept longer charging times compared to conventional charging. Based on data of UK drivers, this study illustrates that providing tailored information to potential users of smart charging systems can increase the likelihood that they choose smart charging over conventional charging. Taken together, the talk will elaborate how (i) the usage of evidence-based behaviour interventions can increase the adoption and usage of key technologies in the transportation domain, (ii) behavioural interventions can be combined with classic policies and (iii) such interventions can specifically target consumer segments that most benefit from behaviour change. Finally, the talk will discuss the ethical dimensions of behavioural interventions aiming to promote more sustainable transportation behaviour.

2 Thematic Sessions

2.1 Mobility behaviour, incentives and economics

Comparing the levelized cost of electric vehicle charging options in Switzerland and Europe

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Decarbonizing road transport is crucial to achieve Switzerland's net-zero carbon emissions by 2050 target. Given the low-carbon electricity mix, the diffusion of electric vehicles (EV) is considered a key element to that end.[1] With rapidly decreasing purchase prices of EVs, charging costs play an ever more important role for the cost of using EVs, and by extension for the comparison of the total cost of ownership of EVs with that of conventional internal combustion engine vehicles (ICEV)[2]. However, comparing fuel costs of ICEVs and EVs is not trivial. While gasoline and diesel costs are very transparent to consumers (i.e. the pump price as gas stations), EV charging costs are not, as they depend on a variety of factors including charging location, charging speed, and time of charging.

This study develops a systematic classification of charging options by power level and charging location, gathers extensive new market data on equipment cost, and employs a levelized cost approach to model charging costs in Switzerland and 29 other European countries (EU27, United Kingdom, and Norway) and for 13 different charging options. These options are then aggregated to typical user profiles. Building on the levelized cost of charging (LCOC) formula recently proposed by NREL for an analysis concerning the United States,[3] we expand their approach drawing on levelized cost methods in the fields of electricity generation, to derive a measure that allows for a consistent application to any charging option.

Our findings demonstrate a large variance of charging costs across countries and charging options, resulting in very different available policy levers to reduce charging costs. For Switzerland in particular, commercial users face comparably high charging costs, driven by significant expenses for charging infrastructure (see Figure). We discuss implications for transport modelers and potential EV owners, as well as policymakers concerned about the transition to EVs for climate change mitigation.

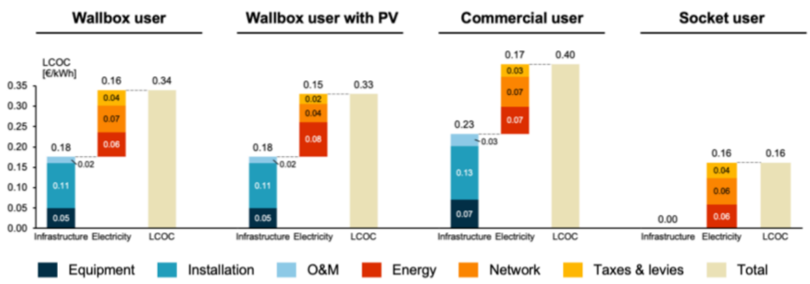

Figure: Cost components of Swiss LCOC in different user profiles in € per kWh of energy charged

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Would you be better off switching to a sustainable mobility lifestyle partly based on electric mobility?

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The future of private car mobility might be dominantly electric, powered by batteries. However, their environmental impact increases significantly with larger battery sizes. Relying still on car utilization, vehicles with smaller batteries (i.e. smaller car, shorter range) should generally be preferred. We addressed this trade-off between vehicle size, range, and environmental impact by proposing two mobility lifestyles with a small electric vehicle (EV), the first in combination with carsharing and the second in combination with public transport. We assume that sharing or public transport is used for trips when the range of the EV is not sufficient, i.e. for trips that exceed 200 km per day. We further proposed a third alternative based on a combination of public transport and carsharing/car-rental without car ownership, as this would result in an even more sustainable mobility lifestyle.

Since total cost of ownership (TCO) for a conventional car is still underestimated and EVs still exhibit higher upfront costs than conventional cars, EVs are often perceived to be costlier. With this research, we wanted to investigate whether it is possible that people might be contrariwise even better off by switching to one of the three alternatives. For this purpose, we calculated the TCO for each proposed mobility lifestyle utilizing the information on stated mobility behavior of 860 participants of the Swiss Household Energy Demand Survey (SHEDS), a representative survey of the Swiss population. For example, we used the average kilometers driven per year, the purchase price of the current car and the number of day trips per year exceeding 200 km. Together with a method developed by Touring Club Switzerland (TCS), which addresses costs related to depreciation, maintenance, fuel and tires among others, we were thus able to calculate the TCO of the participants current car and the TCO of the proposed alternatives.

Results suggest that roughly 63 % of respondents would be financially better off switching to a combination of a small EV for everyday trips until 200 km and use public transport for the cases daytrips exceed 200 km. About 36 % of the respondents would be better off with a combination of a small EV and carsharing/car-rental and 96 % would be better off switching to a combination of public transport and carsharing/car-rental without car ownership. We further tested the effect of a 50 %, 100 % and 200 % CO_2 tax on fuel, which further increases the attractiveness of the alternative mobility lifestyles significantly.

To the best of the authors' knowledge, this is the first study to investigate the TCO of multimodal mobility lifestyles compared to a lifestyle based only on conventional private car use. Our results could be relevant for public policy, mobility planners as well as mobility service providers who could use our results for promoting the cost advantages of alternative mobility lifestyles.

Pigovian Transport Pricing: A Field Experiment

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This study investigates and analyzes the effect of *Pigovian transport pricing* in Switzerland, i.e., personalized pricing of all external costs in transport. The project's core is a virtual transport pricing based on the observed transport behavior of the participants in the experiment. The empirical work of the project was conducted by ETH Zurich, University of Basel, and ZHAW from September 2019 to January 2020. The project was funded by the Swiss Competence Center for Energy Research (SCCER CREST-Mobility Joint Activity), the Swiss Federal Roads Office, and the Swiss Federal Office of Transport.

Pigovian transport pricing is a nearly 100-year-old idea to reduce the external costs of transport to an economy-wide optimum. External costs are all societal burdens that the users themselves do not bear. Ideally, transport pricing takes into account all external costs: emissions of pollutants, noise and greenhouse gases, safety risks and health effects, lack of seats in public transport, and congestion on the roads, but also the operating and maintenance costs for the transport infrastructure. Implementing the idea was technologically impractical for a long time, but this hurdle has fallen due to digitization in recent years. Partial implementations of transport pricing are increasing worldwide, e.g. as congestion pricing in Singapore, London, Stockholm, or as road pricing on German or French highways.

In Switzerland, only surveys and modeling studies have been conducted so far. The MOBIS study went one step further and tested the impact of Pigovian transport pricing in an experiment with 3,700 participants in metropolitan areas in the French and German-speaking parts of Switzerland. It is the largest and most comprehensive transport pricing experiment in the transport sector to date and allows the robust estimation of the effect size for the agglomeration areas in Switzerland.

The core of the experiment is the four weeks during which participants are randomly divided into three equal groups (pricing, information and control groups) and subjected to an information or pricing treatment. To measure the effect of this treatment using a difference-in-differences approach, all participants were previously observed, without treatment, for four weeks. Suitable participants were identified and invited through an initial representative survey. Regular use of a car (at least two days per week) was a condition for participation in the study. At the end of the study, participants received an incentive payment of CHF 100.

After the four-week observation period, the information group received regular information about the amount of external costs their behavior had caused. These external costs were converted to money and presented, but participants did not pay for these costs. The pricing group received the same information for the second phase of the experiment and a budget from which the external costs were deducted. This personalized budget was slightly more than each participant's actual external costs during the first four weeks of the study. As an incentive to reduce the external costs of their transportation behavior, this group was allowed to keep the unspent portion of the budget. In this sense, Pigovian transport pricing was implemented for this group.

The main result of the study is the significant reduction in external costs observed for participants in the pricing group. These participants measurably changed their behavior through shifts in route choice, departure time choice, and mode choice. In particular, participants who understood the concept of external costs in the experiment are responsible for the observed reduction. The short-term price elasticity is -0.31, which is at the same level as for gasoline price increases. Participants in the information group also showed reductions, but not to a statistically significant extent. The results were tested for robustness in a series of tests and confirmed.

The MOBIS study shows that Pigovian transport pricing in Switzerland would have the intended effects and that these could be enhanced by targeted information. It also seems plausible that longer-term adjustments in behavior, which could not be tested in this experiment, would lead to a larger effect.

Mobility: a consumer good, traffic: a force of nature

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My contribution provides evidence from the perspective of discourse linguistics that the frames of mobility and traffic promote non-sufficient thinking and action. The extensive use of these terms in journalism, research, and politics triggers an understanding of mobility as an (immaterial) consumer good available in unlimited quantities and of traffic as a force of nature.

1) Traffic: An analysis of traffic-related metaphors in German language reveal that traffic is largely conceptualized as a **flow** realized in water metaphors: *Verkehrsfluss, Verkehrsstau, Umleitung, Verkehrsinsel, Gotthardröhre* etc. (In English this corresponds to *traffic flow* realized in slightly different lexical metaphors such as *bottle neck, traffic wave, traffic surge,* traffic that *trickles* etc.) My contribution presents some entailments of these metaphorical frames that can be inferred by analogical reasoning:

- If traffic is seen as a flow, it appears to be a natural phenomenon following gravity: Its man-made nature is hidden. → The use of fuel is backgrounded.
- If traffic is a natural stream, traffic policy will have to ease this (natural) flow. → Bottle necks are widened, providing unimpeded streaming. (in German: *Engpässe ausweiten, Abflüsse schaffen, zweite Gotthardröhre bauen* etc.)
- If traffic is a natural flow, motorists are water drops carried by the flow. → Their individuality and responsibility are backgrounded.

2) Mobility: Our analysis of a corpus of Swiss newspaper articles from 2017-19 reveals that mobility is framed as a **market commodity, a consumer good**: e.g. *Mobilitätsangebot, Mobiltätsnachfrage, Mobilitätsmanagement, Mobilitätsbedüfnisse, Mobilität verteuern, Aufwendungen der Haushalte für Mobilität,* etc. The entailments of this metaphor can be inferred as follows:

- If mobility is a consumer good it has a price and is available in unlimited quantities as long as it can be paid for. → The limited space and the limited quantity of natural resources are hidden.
- Political implications: If mobility is framed as an unlimited commodity, it seems worthwhile to establish mobility pricing. However, its hidden materiality (its fossil footprint) would have to be included in its price.

The fact that both metaphorical frames blind us to the use of natural resources invites a discussion of what political action and business models might be suited to manage mobility and traffic. Secondly, it might be interesting to discuss if there are alternative metaphors to frame *traffic*.
My presentation is based on a study completed in the context of the research project *Sprachkompass Mobilität* at CDE Uni Bern (Caviola and Sedlaczek 2020). Further results are published under www.sprachkompass.ch
Methodically our research relies on the principles of discourse linguistics (Bendel Larcher 2015) and frame and metaphor analysis (Lakoff and Johnson 1980, Busse 2012).

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How to incentivise the user-based redistribution in free-floating carsharing? The evidence from Switzerland

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Over the last years we have witnessed a rapid growth in the number of free-floating carsharing schemes. The main challenge of free-floating carsharing operators lies in unbalanced spatio-temporal distribution of vehicles. On the one hand, there are zones with high demand, where efforts are needed to maintain the desired service level. On the other hand, there are the zones with low demand, where vehicles have long idle times. To achieve more balanced spatio-temporal distribution operators have to move vehicles from low to high demand zones. This measure, also known as operator-based redistribution, is costly, energy-consuming and associated with higher CO2 emissions. To address these drawbacks, the so-called user-based redistribution has recently been explored, meaning users redistribute the vehicles. Instead of doing it by generating extra rides, the redistribution is achieved by applying incentive schemes to influence the demand of the users.

In this study, we explore the responsiveness of users of a Swiss free-floating carsharing service (Mobility Go, part of Mobility) to different forms of incentives, promoting user-based redistribution. The goal of the study was to provide the Mobility Genossenschaft with sufficient information to implement a new incentive scheme for user-based redistribution, specifically tailored towards its users, which will be further tested in a field experiment. The study started with two focus groups to capture users' perception of the current incentive schemes and suggestions for improvement. Qualitative insights from the focus groups served as an input to an online survey. The core of the online survey was a discrete choice experiment (DCE), providing hypothetical choice scenarios and exploring preferences for different types of incentives for user-based distribution. The DCE, was divided into scenarios around picking up cars in less busy zones and dropping off Mobility-Go cars in more frequented zones with less cars. The picking scenarios tested four incentives: free driving time, financial discount, collecting points (money) for social or environmental projects and collecting points to enter a lottery for a chance to win bigger prizes. The dropping scenarios tested the same incentives and additionally tested an incentive of a guaranteed parking space to drop the car in specific zones (those with less cars). Additionally, the survey collected further information on (1) the travel behaviour of the test persons in general, (2) the usage of the Mobility Go service, (3) Mobility membership details, (4) attitudes towards current user-based redistribution incentive schemes, (5) follow-up questions related to the discrete choice experiments as well as (6) the socio-demographic questions.

The DCE and survey results, based on a sample size of 194 test persons, suggest that across picking and dropping scenarios users are most interested in receiving free driving time as an incentive, followed by money. In addition, users were equally interested in the guaranteed parking space in the dropping scenarios. Collecting points (money) for social and environmental projects and collecting points to qualify for a lottery were not attractive to Mobility users. Overall, the interest in incentives seems to decrease with age and level of education. Furthermore, Mobility cooperative members showed the least interest in incentives, while owners of an annual subscription, test subscription or other subscriptions showed substantially higher interest in incentives.

2.2 Transport systems, freight logistics, digitalization

Flying to the future: definitions and implications of climate-neutral aviation

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The aviation sector has experienced an exceptional growth in the pre-pandemic decades and is expected to grow further. So far, efforts to mitigate aviation emissions were limited and have only targeted CO_2, yet about two-thirds of the observed warming due to aviation are caused by non-CO_2 effects, such as contrails clouds and nitrous oxide emissions. If demand for aviation will continue growing, these non-CO_2 effects could jeopardize efforts to make aviation carbon neutral. The recent surge in net-zero emissions pledges has left unclarity around what net-neutrality means for the aviation sector, since current definitions typically overlook the importance of non-CO_2 climatic effects.

In this study, we identify and explore multiple definitions of climate-neutral aviation: 1) eliminating all aviation emissions after the onset year (e.g. 2050); 2) stabilizing aviation's climatic effects after the onset year; 3) following a radiative forcing pathway compatible with the goals of Paris Agreement. Using a reduced-complexity climate model, FaIR, we explicitly account for non-CO_2 effects and assess the needs for CO_2 removal under different scenarios of aviation growth and technological mitigation.

We find that the relative importance of non-CO_2 climate effects critically depends on the time-evolution of emissions rather than cumulative emissions. The extent of required CO_2 removal largely varies between definitions of climate neutrality. In scenarios of steady aviation growth, large rates of CO_2 removal are needed to comply with the 1.5-2°C target. Eliminating all emissions and climate effects after the onset date of climate neutrality, as in the first two definitions, does not guarantee to reach a certain climate goal and thus does not substitute for efforts to curb emissions before reaching climate neutrality. Rapidly switching to cleaner forms of flying, i.e. through synthetic fuels and hydrogen aircraft, can however lead to the complete elimination of CO_2 emissions and to a strong reduction of other aviation species, hence enabling to reach climate neutrality with a minimal deployment of CO_2 removal.

Beyond highlighting the challenge of defining climate-neutral aviation, our research maps implications, benefits, and trade-offs of different demand and technological avenues towards climate-neutral aviation.

V2X at Mobility CarSharing

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According to the “Electric Offensive” strategy, the Mobility Cooperative will electrify the entire fleet of around 3,000 passenger vehicles by 2030 at the latest. But despite sharing, electric vehicles (EVs) are mostly “standing vehicles”. Bidirectional Mobility-EVs therefore offer the opportunity be used in large numbers as mobile batteries for V2X services. Mobility would like to test this potential - together with several well-known partners - by means of a P&D project and various research activities.

In the proposed P&D project, technical, organizational and economic solutions are being developed to operate 50 EVs in a grid-friendly manner, without restricting mobility operations and the quality of service for customers, and at the same time offering significant flexibility (10 or even 20 kW per car).

The plan is to test the 50 bidirectional vehicles during normal car sharing operations for 1 year from September 2022. The V2X benefit will be concretized on three grid-levels and the achieved compensation for flexibility will show possible new business models. Thanks to two already approved SFOE research projects, predictive V2X algorithms will be developed together with ETHZ, and - together with HSL - the topic of data quality and security will also be analyzed.

Road infrastructure digitalization for automated vehicles

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Automated vehicles developers are investing and working on improving the algorithms that enable the vehicle to detect markings and signs that it must respect. However, due to problems detection we encounter nowadays, these algorithms do not yet allow us to envisage a level of automation 5 in which the driver no longer intervenes.

Several concrete examples can be mentioned here; Pavement longitudinal joints repairs can mislead the algorithm into thinking it is detecting a continuous line and thus moving the vehicle away from its ideal position, or even putting it in danger; In other cases, markings may be contradictory, degraded or non-existent (e.g. in the case of unmarked central lanes), or the reduction of markings in 30 km/h zones in urban areas may cause problems for line detection algorithms and Elon Musk recently confirmed this : “Moreover, standard Autopilot would require lane lines to turn on, which this street did not have” [1]. In Switzerland, several accidents have been reported on the motorway construction sites involving semi-autonomous vehicles that have not respected the markings or signs in place, even hitting buffer trucks (set up to protect people working on the site) [2].

The solution envisaged here consists of digitizing the transport infrastructure, or the transport infrastructure modifications (construction phases) in order to transmit this information to the automated vehicles. Recent progress made at the HEIA-FR (SwissMoves Group) has made it possible to define the position of the vehicle with an accuracy less than ten centimeters. Furthermore, road infrastructures are already highly digitized and relatively accurate in GIS (Geographic Information Systems) or CAD (Computer Aided Design) tools.

As part of a master's thesis results [3], we were able to convert the plans drawn by civil engineers (markings) into a map compatible with the route planning algorithm used by SwissMoves for its automated vehicles, Lanelet2 [4], with the following process:

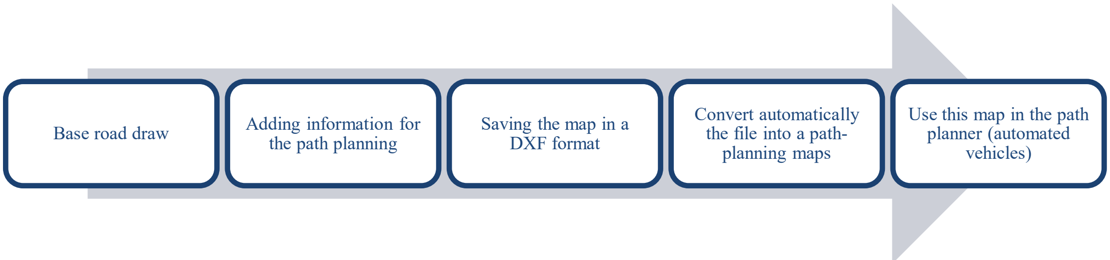

Fig. 1 Conversion process

The first three steps are carried out by draughtsman. When designing the plan, requirements (drawing process) have been established to ensure that all necessary information is included in the draw. While this requires extra work, we have been careful to minimize this. Then the developed converter transforms the draw into a file compatible with the automated vehicles path planning algorithm. Thanks to this process, the map that the civil engineer uses to draw lines on the roads and the map that the autonomous vehicles need are identical, which means that the map is up to date and the drawing work is done only once, as opposed to twice actually.

If the current results show that the conversion of the markings plan into a useful file by the path planning algorithm works and that the information extracted from the draw is well represented in the map understood by the automated vehicles, the future goal is to add the conversion of the road signs in order to obtain fully auto-converted signs (e.g. speed limits, road priorities).

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Projecting technology competition for low-carbon road-freight in Switzerland

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Decarbonizing commercial road-freight vehicles in the Swiss transport sector is an important step to achieving the net-zero carbon emissions by 2050 Swiss decarbonization target[1]. In 2018, commercial vehicles in Switzerland were responsible for 9% of national CO2 emissions and 7.2% of national GHG emissions[2]. Alternative low- or zero-carbon commercial vehicle drive-technologies are slowly entering the market today, but will become increasingly available in the near future[3,4,5]. However, the economic competitiveness of these niche technologies in certain road-freight application segments remains uncertain. Moreover, the dynamics of the transition to low-carbon road-freight vehicles in Switzerland is largely unknown—when will zero-carbon commercial vehicles become prevalent? To assess this transition, we develop a dynamic modeling framework to project future market shares of alternative drive road-freight vehicles in different application segments. Based on a detailed analysis of transport patterns and performance within the Swiss road-freight sector, informed by inputs from the Swiss toll database (Leistungsabhängige Schwerverkehrsabgabe LSVA) as well as from expert interviews, the model identifies key drivers of drive-technology competition. Furthermore, we model and assess different policy options to understand the most effective tools for enabling a swift transition to low-carbon vehicles.

Competition between drive-technologies is modeled by way of investor simulation. First, we assess the initial degree of competition between five drive-technologies (diesel, bio diesel, natural gas, battery-electric, fuel cell electric, hybrid) in nine different application segments (light, medium and heavy-duty vehicles in urban, regional and long-haul ranges) by comparing the total cost of ownership (TCO) over the full lifetime of a vehicle—a metric understood to be representative in determining commercial vehicle purchasing decisions[6]. A probabilistic discrete choice simulation of independent investors then determines the selection of specific drive-technologies in a given year. It is assumed that the drive-technology with the lowest TCO would be the most attractive to a rational commercial investor. Dynamic TCO cost components are modelled as exogenous inputs, though different dynamic cost scenarios for certain components (primarily for the battery pack, fuel cell system and fuel costs) are assessed.

The results show high competition of battery electric trucks (BETs) in Switzerland in the medium- and heavy-duty weight segments. Fuel cell electric trucks (FCETs) in these segments are only able to compete if hydrogen fuel prices decrease significantly over the next years. This cost competitiveness is largely due to a zero-emission vehicle exemption from the LSVA toll levied on all commercial vehicles over 3.5 tons on all Swiss roads. Zero-emission vehicles in the light-duty segment (<3.5 tons), which are not exempted from the LSVA toll, do not display similarly high levels of competition, though are able to gain higher market shares through vehicle cost reductions alone. In analyzing different vehicle and fuel cost scenarios combined with various dynamic toll scenarios, we find the LSVA to be a highly impactful policy tool in Switzerland for decarbonizing the road-freight sector. LSVA policy design can incentivize demand for zero-emission vehicles early in the transition, but it can also hold back zero-emission vehicles from gaining market shares if calibrated improperly. Policy-makers must be cognizant of these tradeoffs when designing appropriate toll measures.

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2.3 Mobility within the energy system: V2X, Synfuels

What does the net-zero emission goal imply for the Swiss transportation sector?

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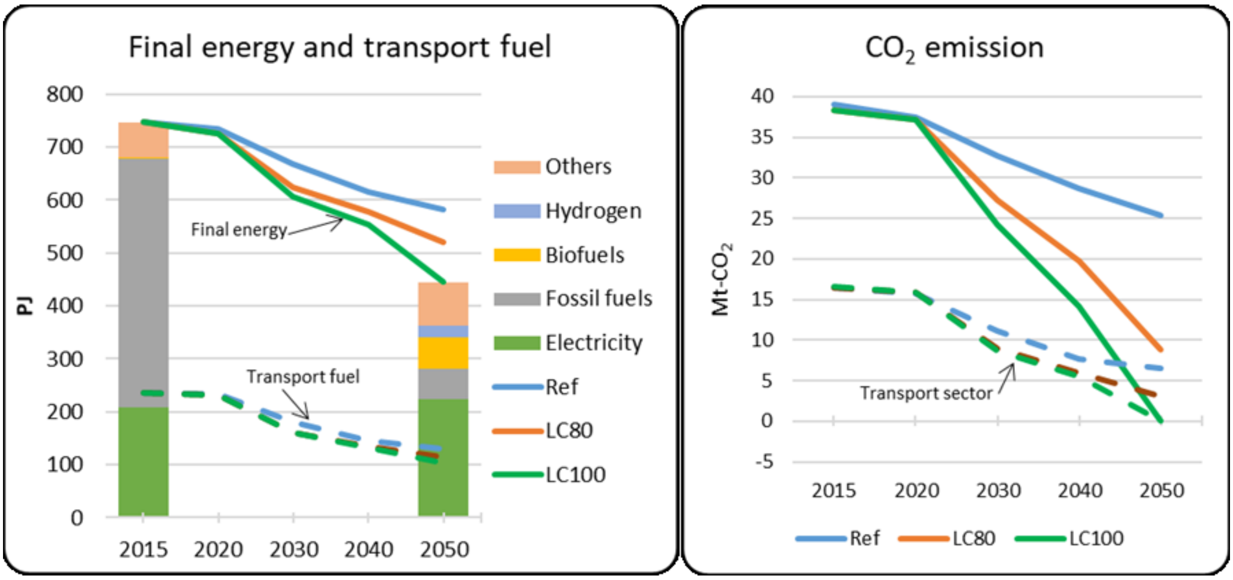
The Swiss government sets out a net-zero emission goal by 2050 while phasing out the existing nuclear energy. This presentation aims to shed insights on the transport sector's contribution to meet this ambitious goal. We use the Swiss TIMES Energy system Model and assess prospective technological pathways. Our scenario results indicate that extensive electrification of mobility increases the total electricity demand. While to a certain extent, electric cars are competitive even if climate would not be the priority, carbon neutrality requires a boost for electrified mobility where battery-electric vehicles along with plug-in hybrid electric vehicles are largely evolving as a cost-efficient mobility solution particularly for small to medium size car segments while fuel cell cars are emerging as potentially attractive option for big size car segments. Four out of five cars are electric by 2050, which alone requires about 5-9 TWh of electricity. Hybridization of buses and trucks emerges as a competitive option but they are propelled with bio- and synthetic fuels. The transport sector emerges as a major driver for the deployment of hydrogen in the energy sector in the long-term.



Left panel shows the trajectories of the final energy demand (solid lines) and transport fuel (dashed lines). Final energy mix in 2015 and 2050 for the LC100 scenario is also shown in the left panel. Right panel elucidates CO_2 emission trajectories of the whole energy system along with the tailpipe emissions from the transport sector

Synthetic Fuels for Switzerland

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To achieve net zero greenhouse gas emissions by 2050, global CO_2 emissions in the transport sector must be reduced from 7. 23 gigatons today to 0. 69 gigatons by 2050 [1]. Electrification will play an important role but in several transport applications, chemical energy carriers and combustion based energy conversion will remain important. This is particularly true for long haul transportation like heavy-duty trucks, shipping, and aviation. (Figure 1). Switzerland has set similarly demanding reduction targets. Scenario analyses in the Swiss Energy Perspectives 2050+ show that between 52 to 119 PJ synthetic fuels would be needed domestically to reach the country's net zero goal in 2050. (Figure 2). International aviation would demand an additional 59 PJ of power-to-liquid fuels.

To achieve the net zero goal, fossil fuels must be replaced with nearly zero emission fuels generated from biomass, waste, or electricity. Biomass based fuels are already in the market, primarily in blends with fossil fuels. In Switzerland importers of fossil motor fuels started blending fossil fuels with biofuels in 2014, due to the obligation to reduce CO_2 emissions. Until 2019 the use of liquid biofuels rose from 73.3 million L to 260.2 million L.

Synthetic fuels generated from electricity are not jet commercially available in large quantities, but are being investigated in a broad range of research and demonstration projects worldwide. Public and private sector research in Switzerland is focussing on synthetic fuels such as hydrogen, ammonia, DME (dimethylether), and OME (polyoxymethylendimethylether), exploring applications in engines for heavy duty trucks, shipping or construction and agriculture machinery.

The global impact of the know-how and technology solutions developed in these projects is facilitated through global research networks, for example in the Advanced Motor Fuels Technical Collaboration Programmes (TCPs) of the International Energy Agency IEA. . [3]

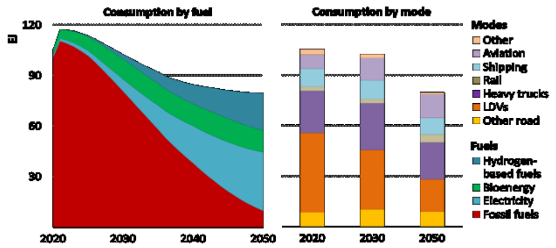

Fig 1: Global transport final consumption by fuel type and mode in the NZE [1]

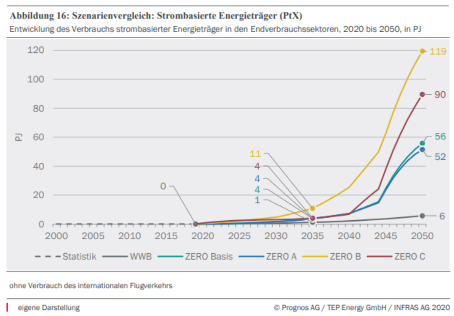

Fig. 2 : Consumption of synthetic fuels in Switzerland without international aviation for different scenarios [2]

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How much vehicle-to-grid is feasible without compromising EV warranties?

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As the integration of renewable energy sources drives the decarbonization of the energy system, the requirement for flexibility in the grid grows. The concept of utilizing idle grid-connected electric vehicle (EV) battery packs for grid applications, known as vehicle-to-grid (V2G), is emerging as a promising solution for overcoming the intermittency of renewable generation and maintaining grid stability.[1,2]

However, the potential of V2G is constrained by battery degradation. Secondary use of EV battery packs for V2G leads to additional battery degradation, and the resulting lifetime reduction determines the technical feasibility of using V2G for the given application. While there is a general consensus on the technical feasibility of V2G in certain scenarios, the impact of V2G applications on EV lifetimes remains a source of uncertainty for academia and industry. Furthermore, while EV warranties are a key parameter for determining viable V2G business models, this is not reflected as a benchmark in extant literature. Due to this ambiguity, the allowable utilization of V2G across applications is not quantified, and consequently the potential contribution of V2G as a building block of the energy infrastructure remains unknown. In this study, we address the question of how much V2G is feasible in the bounds of EV warranty agreements.

Adapting a physics-based degradation model[3], this work models battery degradation, and thereby lifetime for V2G scenarios for four key grid applications. Realistic, standard, and repeatable profiles for grid applications,[4] and EV driving[5] are adapted for V2G systems. The explored scenarios incorporate the impact of technical constraints such as V2G state-of-charge (SOC) limit, operation strategy and V2G schedule. This assessment is applied to the three prevalent cell types, namely lithium iron phosphate (LFP), lithium nickel cobalt aluminum oxide (NCA) and lithium nickel manganese cobalt oxide (NMC), cathode batteries with graphite anodes. As such, our study provides a comprehensive picture of the impact of V2G on EV battery pack lifetime. Comparison to warranty limits for lifetime and distance (or throughput) enables quantification of the allowable limits of V2G utilization based on current EV battery pack technology.

Our results show large variance across combinations of cell type and grid applications. While using EVs for peak shaving has a marginal effect on battery life (with an average lifetime decrease of 3% for LFP and NCA, and 11% for NMC), performing wholesale arbitrage can have a much larger impact on degradation. Yet, this effect differs strongly between cell types. The respective throughput that can be used for V2G without compromising EV warranties consequently differs strongly between combinations of cell type and grid application. Correspondingly, energy system models and life-cycle assessments assuming very generous use of V2G might have to be adapted. Based on our results we discuss the implications for energy modelers and other academic researchers, industry (including V2G business models) and public policy.

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Current V2G research at ZHAW

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Vehicle-to-grid (V2G) technologies and infrastructures have the potential to be a major component of the on-going sustainable transition of the transportation sector, creating decarbonisation synergies through sector coupling: efficient mobilisation of complementary innovations in sectors such as electricity or ICT. Since 2017 ZHAW-INE is involved in several V2G research projects, with additional projects being in the planning and kick-off stages. In this talk we give a short overview of selected projects in terms of use cases, levels of analysis, settings and aims of the projects. While the presentation will not include final results, we will refer to existing publications, interim results and planned project outputs.

2.4 Technical progress: alternative drives and optimization

Hydrogen Mobility

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We shall first present the concept of combined service stations for electric vehicles (EV) and fuel cell electric vehicles (FCEV). This service station is based on a vanadium-manganese redox flow battery, which serves two purposes:

-1- Providing a fast charge of EVs *via* a DC-DC transformer. This allows to address the stochastic arrival of vehicles without the need of over-dimensioned grid supply[1].

-2- Producing hydrogen chemically on-site *via* the chemical reduction of protons to hydrogen through the chemical oxidation of Vanadium (II) thereby discharging the negative side of the battery. The balancing of the battery is achieved *via* the chemical oxidation of water to oxygen and protons through the chemical reduction of Manganese (III) also discharging the positive side of the battery[2].

All in all, the battery (*e.g.* MW-*n*MWh) can be charged when convenient by the grid and discharged electrically by charging EVs or chemically by producing hydrogen.

In the second part of the talk, we shall present the GreenGT-H24 hydrogen race car and discuss the challenges provided by a racing track.

Finally, we shall present the GreenGT fuel cell demo truck being currently assembled in Switzerland by Larag.

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Progress in Internal Combustion Engines for Efficient and Flexible Drive Trains of Mobility

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Today, mobility and mobile machinery heavily rely on internal combustion engines (ICE) which are fuelled with fossil primary energies. Although hybridization of various degrees, up to full battery-electric solutions, is becoming increasingly important for certain segments, further advancements for ICEs are necessary to make them as efficient as possible and well-suited for renewable fuels, especially for long-distance and high-power applications.

There are efforts in various fields to improve the efficiency of ICEs, such as friction reduction, an increase of the compression ratio, reduction of wall heat losses, dethrottling for improved part-load operation, enhanced boosting concepts, or new combustion concepts with pre-chamber or pilot ignition for higher thermal efficiency. For a significant reduction in fuel consumption, these new measures must be applied to a wide range of operating points. The key to success is variability. With a variable injection, compression ratio, boosting, exhaust gas recirculation, and valve timings, each operating point can run at its optimum.

At Empa, we developed a fully variable electro-hydraulic valve train system called FlexWork [1]. Our engine control software allows setting the valve timings of each cylinder individually. This enables the control of the engine load by an appropriate valve opening duration instead of adjusting the conventional throttle. Furthermore, cylinder deactivation is possible without any additional effort. These measures lead to fuel savings of 10-20% in typical driving cycles [2,3]. Moreover, variable valve timings enable new combustion strategies such as 6-, 8-, 10-, or named generally x-stroke operation. Similarly to cylinder deactivation, the load of a single combustion is increased, but in contrast, all cylinders remain active. Thus, a low engine load is achieved with a high stroke number, which leads to a high specific cylinder charge for each combustion with high thermal efficiency [4].

The flexibility of the valve train in combination with new combustion concepts enables the ICE to adapt to various synthetic fuels, all digitally. The effective compression ratio is adaptable via the intake valves, the exhaust gas recirculation via the exhaust valves, such that the varying ignitability of various synfuels is accounted for. Furthermore, current investigations have shown that the electric propulsion part, including motor and battery, in hybrid electric vehicles can be reduced in size without loss of optimality, if the implemented ICE operates more efficiently. This leads to a reduction in weight, but also to more cost-effective vehicles.

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Prediction of the real world consumption values for heavy-duty vehicles with different propulsion technologies

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In the context of Switzerland's climate goals and with regard to potential future requirements for the on-road freight transport sector, decarbonisation of the transportation fleet is becoming an often-discussed element. Transport companies and fleet owners encounter emerging new technologies in the heavy-duty range and are exposed to the associated challenges to follow the company's own climate strategy. In this light, Empa has developed and validated a real-world consumption model for heavy-duty vehicles as part of an innovation partnership with the Federation of Migros Cooperatives (Migros Genossenschaftsbund - MGB). The algorithm is used to estimate predictively the road-based consumption and the associated CO_2-emissions for different heavy-duty drive technologies, including diesel, biogas, battery-electric and fuel cell propulsion systems. This algorithm has been implemented in MGB's supply chain management system, named LT^{OPEX}-Tower®, which is used to monitor, coordinate and control the flow of goods within the supply chain[1].

The incorporated model uses a simple Willans-approach to calculate the *tank-to-wheel* consumption of the considered freight transport, independent of the application and its propulsion system, in a predictive manner. The vehicle specific data and route information serve as initial variables for the comparative assessment of the aforementioned drive technologies and predicts the energy-efficiency for the given vehicle and route parameters with respect to predefined boundary conditions. Furthermore, the tool also considers the pre-chain of the energy carrier, i.e. the path of production and distribution in *well-to-tank* perspective. In a future development, life cycle parameters of the vehicle and its energy storage and conversion system (e.g battery, fuel cell, electric motor) will also be included.

Under the given title, the basic methodology and used approach for development of such calculation framework will be presented.

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