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Proceedings

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This conference is organized by the World Conference on Transport Research Society (WCTRS) Special Interest Group (SIG) f2 on Transport, Climate Change and Clean Air. The focus of the conference is on current transport, climate change and local air pollution research, including the application of scientific methods on impact assessment or evaluation that will provide policy insights on efficient mitigation and adaptation measures for the transport sector. Such measures will include changes in various types of policies and mobility patterns, as well as technological innovations and disruptions.

The objective of this conference is to have fruitful discussions within each thematic field with national and international experts. Key outcomes from the discussions will be drafted as inputs to the 2018 Talanoa Dialogue, which is a facilitative dialogue whose inputs will be synthesized and presented at COP 24. It will contribute to the UNFCCC process to enhance Parties' ambition and help Parties with the preparation of NDCs.

Thank you for joining our conference and contributing to the Talanoa Dialogue,

Wei-Shiuen Ng
International Transport Forum (ITF)

Yannick Perez
Centrale Supélec

Patrick Jochem
Karlsruhe Institute of Technology (KIT)

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Key Note 1:
Prospects for electric vehicles and their potential to mitigate GHG emissions

Frances Sprei, Chalmers

Frances Sprei's research assess different personal mobility options, such as alternative fueled vehicles and electric vehicles as well as innovative mobility forms such as car sharing and ride sharing. Economic, political, technical and behavioral aspects are taken into account. Her research methods are interdisciplinary combining quantitative methods such as econometrics with qualitative methods such as interviews. She has been the co-chair of the Behavior Energy and Climate Change conference and received in 2010 the Jan-Eric Sundgren Award.

Optimal Policy and Network Effects for the Deployment of Zero Emission Vehicles *

This Preliminary Draft April 2018

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Executive summary

Emissions from land transport are a major source of greenhouse gas emissions (approximately 24 % for the EU28). Urban pollution, in particular particulate matter (PM2.5) and ground level ozone, is causing 3 millions of premature deaths yearly. Battery and fuel cell electric vehicles (BEV and FCEV respectively) are thought to be attractive technologies to face these societal challenges. However, with the exception of Norway, the current market shares remain quite low for BEV and anecdotal for FCEV. The common explanations for this slow penetration are: the high price of electric cars, their limited range and the lack of filling infrastructure. The last two issues explains "range anxiety": the fear of running out of power.

We formalize the interaction between three major factors that drive the deployment of zero emission vehicles: indirect network effects for adopters (i.e. range anxiety), scale effects to reduce the cost at the production stage (learning-by-doing and spillovers), and the degree of competition in the market with its influence on the price of cars. These three factors are embedded into a static partial equilibrium model. Consumers derive utility from transportation and incur a utility loss from filling. Consumers pay for the car, the fuel but not for the stations themselves. The benefit derived from the size of the network of stations is unpriced. Each firm production cost depends on the aggregate car production through a scale effect. Car producers compete à la Cournot. Filling stations are price-takers on the fuel retail market, and each has a limited capacity (convex cost).

Our analysis explores various stages of deployment: take-off, building-up and expansion stages. From an economic standpoint our three factors may be interpreted as three externalities, or market failures, which may induce a distorsion between the market equilibirum and the social optimum. The relative magnitude of the distorsion will depend on the stage of deployment. At the take-off stage we may have a degenerate market equilibrium with no cars while the social optimum would imply a positive deployment. At the building-up stage there may be three market equilibria, the equilibrium with the largest deployment generating the highest welfare. The intermediate equilibrium is a tipping point. Indeed if the initial market position lies below the intermediate equilibrium it will converge to the lowest one while if it lies higher it will converge to the preferred equilibrium. At the expansion stage the distorsion is reduced and eventually disappears as the significance of externalities decrease with the size of the market. For each possible stage we investigate the joint optimal subsidies for infrastructure and car adopters (i.e. price rebates) so that the social optimum can be implemented as a market equilibrium, i.e decentralized through market forces.

Our results are illustrated with data on hydrogen cars (FCEV) based on Creti et al. (2018). According to our calibration, a subsidy of approximately 80 % of the fixed capital cost of a hydrogen retailing station and a rebate of approximately 10 % on the listed price of cars would be necessary at the take-off stage. If the market is stagnating with a low deployment, strong public-private initiatives involving temporary demonstration projects, may be needed to pass the tipping point. The total level of subsidies would significantly increase as the deployment builds-up to eventually vanish as market failures disappear. A side result of our analysis shows that if the regulator can only subsidize vehicles or infrastructure, but not both, the return in welfare terms and in the size of the car park is higher with the former policy instrument.

Our static model has the advantage of providing analytical solutions and explicit guidelines for policies. It provides a framework which fits rather well with the observed deployment of electric vehicles in Norway as extensively discussed in (Figenbaum, 2016). However it should be considered as a first step to build more elaborate analytical models, in particular dynamic ones. Indeed a dynamic model would be more appropriate to analyze the efficiency of the many instruments that have been put in place by authorities in different megalopolis in reaction to the growing concern with urban pollution. Ideally the interaction between the various technologies such as BEV and FCEV with these policies should also be introduced. This is the direction followed by Harrison and Thiel (2017). We think that our model provides a useful complement for the interpretation of such large complex models.

Keywords: E-mobility; network effects; joint incentives for infrastructure and car rebates

Abstract

We analyze the impact of indirect network effects in the deployment of zero emission vehicles in a static partial equilibrium model. In most theoretical analysis direct and indirect effects are conflated, and relatively few authors have explicitly considered indirect network effects. We also introduce the market power of vehicle producers and scale effects in the production function. The model exhibits a multiplicity of local social extrema and of market equilibria, suggesting a possibility of lock-in. The optimal set of subsidies is derived so that the Pareto dominating market equilibrium would coincide with the social optimum. This framework is applied to the case of the fuel cell electric (hydrogen) vehicles.

JEL Classification: Q55, Q42, C61

Keywords: E-mobility; network effects; joint incentives for infrastructure and car rebates

Sustainable Transportation Systems on Islands: A Closer Look at Today's Situations and Future Mitigation Potential Mauritius

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The importance of moving towards sustainable transportation systems is critical to achieving a holistic, environmental-friendly pathway for development on island states (UNFCC, 2015). These nations have been at the forefront of the fight for climate justice; yet lags behind in their quest for sustainability while simultaneously facing a myriad of issues. Islands are traditionally perceived as being an antidote to congested and polluted mainland roads (Ratter, 2018). Yet as rapidly developing and urbanizing economies, they are proving to be promising case studies from a transportation perspective, by exhibiting most of the problems & symptoms associated with mobility faced globally along with land constraints, congestion, air pollution, and accidents. In this context, islands have proven to be ideal testbeds (Chmiel, 2015). The closed, insular system allows for a comprehensible overview on effects of infrastructure and transportation changes. Findings are then easily transferrable to larger countries. Choosing a small island developing state (SIDS) such as Mauritius allows for the illustration of progressive decarbonization scenarios for its transport sector within clearly defined system boundaries.

Current academic papers have so far concentrated on the past and importance of the transport sector in Mauritius as well as its numerous negative impacts and the effects on the socio-economic and environmental aspects (To, 2017) (Ramphull, 2017) (Khoodarath, 2016). Policy wise, various white papers and strategy guidelines have repeatedly pointed to a more climate-friendly and efficient transportation system (Smart City Scheme 2015 and Maurice Ile Durable 2014). Although the performance of urban transport is crucial for a long term sustainable Mauritian economy, there is a lack of integrated study targeting islands to enhance the sustainability performance of urban transport.

Our work targets to fill this research gap by providing relevant data and key performance indicators (KPIs) so as to identify potential low carbon pathways for Mauritius' transport sector. We start by mapping the current transportation landscape and its effects, so as to develop a comparative methodology to access the sustainability performance of a mixed set of transportation options available. By setting the vehicle choices of the Mauritian society against a set of environmental and socio-economic key performance indicators (KPIs) – greenhouse gas emissions, air pollution, and congestion -, we are able to evaluate and interpret future sustainable development plans. To understand the planned trajectory of possible future scenarios, the KPIs are developed to provide benchmarking standards.

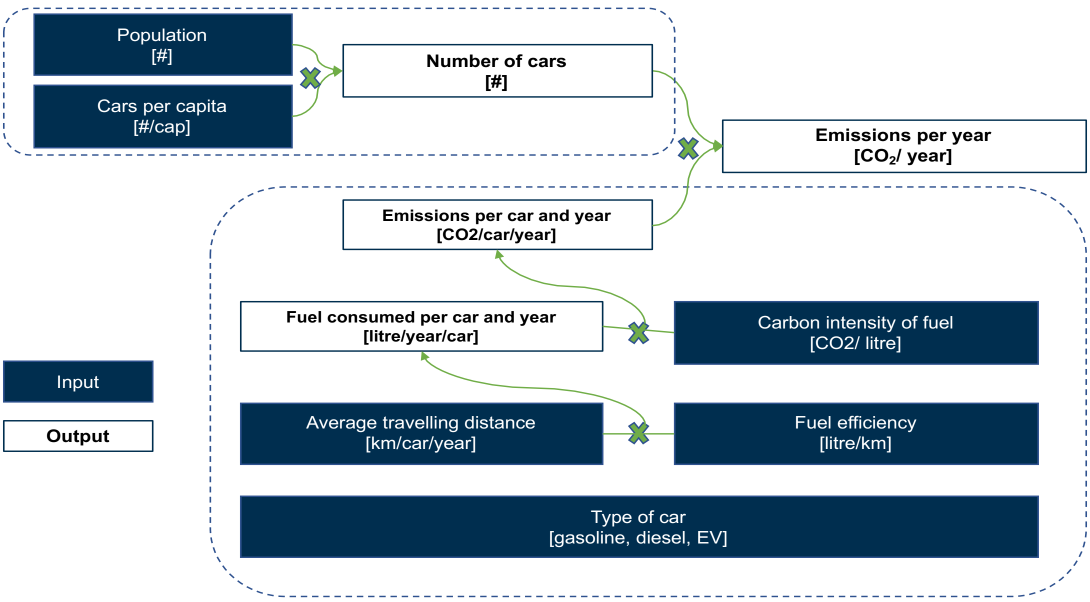

Figure 1: Methodological Approaches for Analyzing Potential Sustainable Transport Trajectories

The latest figure of the island's total GHG emissions were estimated to be 5.37 million tons. The amount of CO_2 emitted from the transport sector is estimated to be 20% of the total emissions. The number of vehicles rose from 319.000 in the year 2006 to 531.000 in 2018 which is representative of an increasing growth of 52% from 2006 to 2018. During the same period, the motorization rate escalated by 38% from 255 to 420 motor vehicles per thousand people.

The majority of vehicles on the Mauritian roads are based on combustion technology. (Statistics Mauritius 2018) Gasoline cars are the most prevalent at approximately 356,000 (2018) and with proportionately the highest amount of greenhouse gas emissions at 385,000 tons of CO_2 equivalent. Diesel cars accounted for 150 ,000 of privately owned vehicles and are responsible for 114,000 tons of CO_2 equivalent. To analyze the first KPI (ecological integrity), we consider fuel efficiency, vehicle type, km/car/year driven by the average Mauritian user, fuel consumption, and CO_2 per liter. This enables us not only to grasp the current carbon emission but also how different scenarios might play out in regard to emissions.

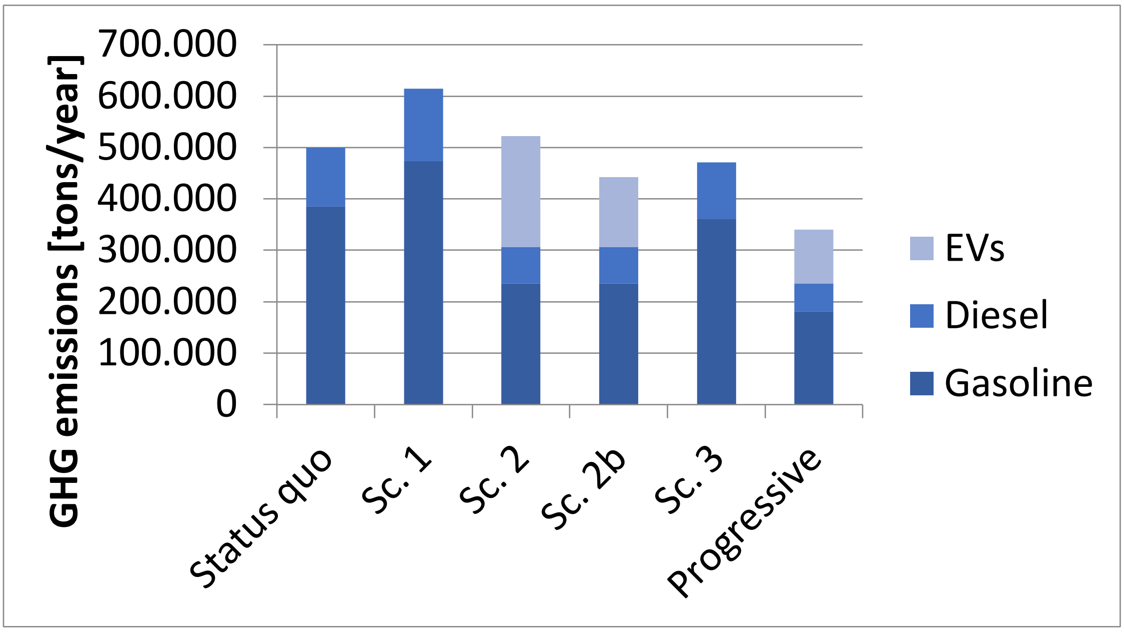

Figure 2: Comparison of GHG emissions of the scenarios

Continuing on the Business as Usual pathway will result in a 23% increase in emissions at 613,000 tons of CO_2 equivalent. Adding electric vehicles to the fleet by 50% also drives the emissions up to 522,000 tons of CO_2 equivalent; mostly due to the current energy mix. However, replacing half of fossil fuel power generation with renewable energy sources results in a decrease of emission by 11%. A cap on cars at the current level influences the carbon emissions by reducing the total by 28,000 tons. Even applying the most progressive scenario of combining a cap on cars with both EVs in the fleet and an energy mix based on 50% renewable energy sources leads to CO_2 emissions reduction by only 32%. Considering the substantial efforts in infrastructure and policy behind this scenario, the reduced level of emissions is considerably less. This shows the future pathways must look private vehicle ownership and include potential public transit and Mobility as a Service scenarios.

This paper presents the current transportation situation of Mauritius and the technologies that have the potential to transform the island in aiding it to achieve carbon neutrality. For further research, we will continue to develop our scenario building to showcase possible options in relations to the KPIs for a more holistic transport transition. In the absence of such mitigation actions, the transport sector emissions will overtake projected one and thus becomes a major barrier to both an equitable sustainable society and avoiding climate change impacts.

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MODELLING THE ENERGY TRANSITION IN THE RUHR AREA

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Background

Climate researchers agree that anthropogenic greenhouse gas emissions significantly contribute to climate change, and that radical measures to reduce greenhouse gas emissions and to adapt to the impacts of no longer avoidable climate change are needed. The German Advisory Council on Global Change (WBGU) in its expertise of 2011 called for a societal contract for a great transformation to implement these radical measures, i.e. a process of change also of cultural identities and established value perceptions and action patterns in politics, economy and private consumption. In its expertise of 2016 the Council emphasised the central role of urban and regional planning for the achievement of this transformation. The German Federal Government with its Climate Protection Plan 2050 reinforced its target to reduce Germany's greenhouse gas emissions by 80 to 95 percent compared to 1990. The state government of North-Rhine Westphalia with its Climate Protection Law of 2013 plans to reduce the greenhouse gas emissions of the state by 25 percent by 2020 and at least 80 percent by 2050. The achievement of these targets requires nothing less than a fundamental transformation of spatial planning.

This fundamental transformation will affect mobility and transport in cities. Daily mobility and transport today account for about one fifth of the greenhouse gas emissions of urban regions. Because of technical progress, travel times and costs will continue to decrease and so induce more rather than less personal mobility. Therefore urban mobility and transport will constitute an important policy field of the transformation called for by the WBGU. But mobility and transport cannot be analysed separately but have to be assessed together with urban spatial development, i.e. decisions by households and firms where to select their residences or to locate their businesses. Urban mobility planning and urban land use planning therefore need to respond to the challenges of climate change together in an integrated way.

However, the present practice of urban planning in Germany does not seem to be able to cope with these challenges. Since the 1970s, with the advent of neoliberal economic principles and, at the same time, the idea of communicative bottom-up planning, the demand by public planning authorities for scientific, analytical-rational planning support has decreased. The result is that ambitious greenhouse gas emission targets have been concluded by the European Union, by EU member states and by regions and cities (see above), but that, because of lack of reliable information on what needs to be done to achieve these targets, necessary action is largely missing.

Methods and Data

This is why in the planned presentation a methodology to scientifically assess the likely impacts of possible combinations of policies or strategies to reduce the greenhouse gas emissions of urban mobility and transport will be proposed and partly demonstrated, using the Ruhr Area, the largest conurbation in Germany, as an example. The focus will be on policies to reduce the greenhouse gas emissions of mobility and transport, but because of the interactions between urban transport and land use, the perspective will be an integrated one combining urban transport, land use and environment.

To accomplish this, the presentation will start from the methodology developed in a research programme funded by the private foundation Stiftung Mercator in the years 2013-2016 to promote knowledge and awareness of the necessity and challenges of the energy transition in the Ruhr Area (Schwarze et al., 2017, Reutter et al., 2017, 2018).

In that project an integrated simulation model of urban land use, transport and environment was applied to the Ruhr Area based on detailed land use and multimodal transport network data. The model includes submodels of demographic and household development, the regional labour market, the markets of residential and non-residential buildings, the land and construction markets and a multimodal travel model and predicts the interactions between these submodels and the travel model in response to policies in the field of land use and transport (Wegener, 2018). The output of the model consists of maps and trajectories of socio-economic indicators, such as population, households, migration, employment, dwellings, land use, accessibility, attractiveness, travel by trip, capita and mode, and environmental indicators, such as CO_2 emissions.

In the project the model was used to assess the impacts of long-term scenarios until 2050 of a large number of policies and policy combinations on greenhouse gas emissions in 687 neighbourhoods of the Ruhr Area until the year 2050 taking account of exogenous assumptions about regional economic development, net immigration and technical and behavioural trends. A large number of mobility and transport policies were examined singly and in combination with each other, such as promotion of electro mobility, area-wide car-sharing, reduction of fuel consumption, regional cordon charge, reduction of lanes on main roads, area-wide speed limits, increase of parking charges, new public transport lines, increase of public transport frequency, free public transport, promotion of cycling, express cycling routes and promotion of walking.

Results

The results of the policies simulated can be summarised as follows: By the combination of successful policies energy consumption and greenhouse gas emissions of transport can be reduced until 2050 by two thirds compared with 1990. Push-measures as high energy prices, speed limits or reduction of the number of lanes of main roads are more effective in reducing greenhouse gas emissions than pull-measures as the promotion of cycling, walking, electric cars or public transport. There can be positive or negative synergies between policies or policy packages, i.e. the impacts of measures can reinforce or weaken each other. The results show that even with ambitious policies the greenhouse gas emission targets of the national and state governments will not be achieved and that even more radical policies are needed.

In the presentation it will be explained how the policies simulated were implemented and combined with each other in the simulation model, and what assumptions about technical and behavioural trends were made until 2050. In addition, it will be discussed how the additional trends can be integrated into the model, such as telework, online shopping, local goods transport, autonomous vehicles, Internet of Things and Industry 4.0.

One of the major issues in this discussion will be the question to what degree technical innovation will have an impact on behavioural attitudes of travellers, house owners and consumers in the long run: Will their behaviour significantly change, or will anthropological, physical or natural constraints will remain constant over time, even under dramatically changed conditions? Because of the large degree of uncertainty of these explorations into the far-away future, the results will not be a single forecast but a number of scenarios resulting from different possible assumptions.

Conclusions

The conclusions of the paper corroborate the result of previous work that much more radical policies are needed to achieve the greenhouse gas emission targets of national and state governments.

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THE POTENTIAL ENERGY USE AND CO2 EMISSION REDUCTIONS OF ELECTRIC TRUCKS POWERED BY OVERHEAD LINES

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Overview

Despite the limited stock of vehicles, heavy duty road transport is responsible for a major share of green house gas (GHG) emissions in the transport sector. In contrast to passenger cars where plug-in electric vehicles are widely considered as valid option for emission reduction, it is less clear which technology is best suited for heavy duty road transport. Here, we give an overview of the techno-economical opportunities and challenges for electric trucks powered by overhead lines, also known as catenary hybrid vehicles or trolley trucks. We focus on the time until 2030 in Germany and find that (1) hybrid trolley trucks with an additional internal combustion engine are best suited for a market introduction, (2) these trucks can be cost-effective for some vehicles by 2030, (3) the required infrastructure can be cost-effective for an operator if part of the fuel cost savings is regained by the operator, (4) the impact on the energy system is limited. Our findings show that trolley trucks are an interesting option that require further research.

Methods and Data

For the analysis of HDT in Germany, we use the data set "Kraftfahrzeugverkehr in Deutschland 2010" which is a travel survey of about 70,000 vehicles with all vehicle movements on one day of observation (KiD 2010). This data set is publicly available and the largest sample of commercial vehicle movements in Germany. Based on the size class information, we can filter for vehicles with an allowed total weight of 40 tons and arrive at N = 1,018 vehicles for our analysis. We only use two attributes of the sample: the annual vehicle kilometres travelled (VKT) and the VKT on the day of observation, both reported in an accompanying questionnaire to the data collection.

The potentials for trolley trucks will be analysed in several steps and the required methods will be introduced in the following. The technical potential is assessed by identification of the highly used highway sections and which share of heavy duty traffic is operated on them. In a second step, the costs from a user perspective will be calculated following by the assessment of sales shares based on costs. Finally, the impact on the energy system will be analysed.

Results

The first group of results concerns the technical potentials of trolley trucks. Trolley trucks can only drive with electricity if they are connected to the overhead cable. We obtain $s_h = 1 - \exp(-\mathrm{dVKT}/L_0)$ with $L_0 = 127.3$ km from a least squares regression of the survey data. We thus obtain the share of km driven on highways. Figure 2 shows the resulting share of mileage of heavy duty vehicles sm over the share of highway kilometers ordered by their usage based on Wietschel et al. (2017). Thus, if the most frequented 20% of highways had overhead lines, almost 50% of the mileage of heavy duty vehicles would be electrified. For example, if 2,000 km or 17% of the German highway network were equipped with catenaries, we would obtain a share of s_m=39% of HDT-km were under the catenaries. The product of the share if driving on a highway sh and of driving on a highway with catenaries sm results in the overall share of km driven electrically s_e.

The economic evaluation of trolley trucks is based on TCO analyses for the individual annual VKT (cf. methods section). The first major economic result here is that overhead line trucks with a diesel engine as a hybrid component can be an economically viable solution for some heavy commercial vehicles. However, this does not include the costs for constructing the overhead power lines and assumes the lines are used to capacity. Other studies come to a comparable result in this respect (den Boer et al. 2013). The TCO for trolley trucks, however, depend on the amount of overhead line infrastructure. We find a relatively low break-even point in TCO between the diesel and trolley truck which ranges between 30,000 and 70,000 km depending on the extension of overhead lines. This stems from the fact that a comparatively low number of electrical vehicle kilometres on the overhead line per trolley truck - 20,000 to 30,000 km/year - is sufficient to amortize the additional costs of converting a conventional diesel truck to a trolley diesel truck. As part of the hybrid propulsion system, the diesel engine guarantees the flexibility of use of the trolley truck when this is driven off electrified roads. For the possible market diffusion of trolley trucks, we find that approx. 25 % of the stock of trucks with more than 12 t allowed gross weight (approx. 50,000 to 70,000 trucks) could be trolley trucks by 2030. The time needed to construct infrastructure, develop and build trolley trucks and replace existing trucks should not be underestimated. In the long term, approx. 80 % (ca. 250,000 heavy duty trucks) of the heavy goods vehicles could be operated on German roads when considering cost-effectiveness from a user's perspective.

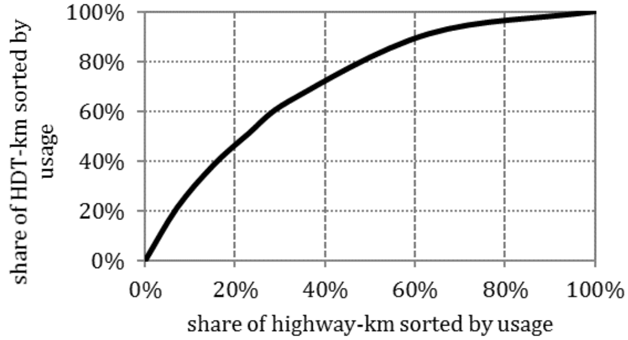

Figure 1: Share of mileage of heavy duty trucks over share of most frequented highway kilometres

The cost for the catenary infrastructure has been assumed to be 2.2m EUR/km (Wietschel et al. 2017). Investments in the overhead line infrastructure would thus amount to approx. 8 to 10 billion euros for this case. The question is whether this overhead line infrastructure can create enough savings to cover its own cost. We show the annual cost for additional overhead cable infrastructure and the savings from the usage of trolley trucks in relation to the length of the overhead lines infrastructure in Figure 2 in 2030.

From an energy management viewpoint, trolley trucks may mean a considerable increase in power demand (by approx. +1.6 % (ca. +8 TWh/a) for 60,000 trucks and approx. ca. +7 % (ca. +36 TWh/a) for 250,000 trucks). Demand varies widely by region and the load and demand can increase by up to 30 % in certain rural regions with an overhead line motorway. Large additional loads are expected especially at very busy motorway intersections in rural areas. However, because the deployment of renewables often also takes place in rural regions, there may well be positive effects for the system integration of renewables.

A challenge in terms of energy management is that heavy trucks represent a largely inflexible demand and, in addition, this demand occurs more during the day and on weekdays. This significantly increases the peak load on weekdays (+ 2 GW in 2030 with 60,000 trolley trucks). This results in new flexibility having to be made available at other points of the energy system, for example via electricity storage, grid expansion or load management.

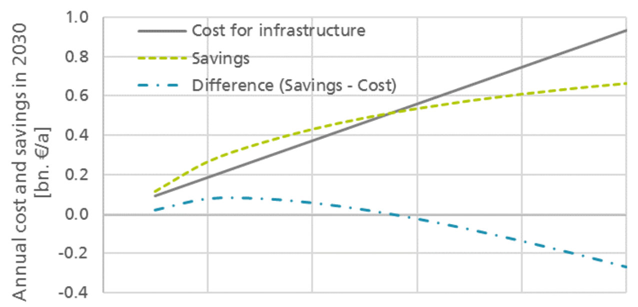

Figure 2: Annual cost for overhead line infrastructure and fuel cost savings from trolley trucks in 2030.

Conclusions

The analysis leads to following conclusions. In the mass marked overhead line trucks could be economic. They could reduce significantly the GHG emissions of the transport sector, if the electricity will come from renewables or other GHG-free sources. Only a limited number of highways has to be equipped with trolley systems due to the high concentration of trucks on certain highways, which lead to limited infrastructure investments. However, a lot of serious barriers for the introduction exist. The infrastructure has to be pre-financed and the state has to play here a active role. Acceptance is critical from different viewpoints. German and European policy makers, truck producers as well as trolley truck users have to be convinced. Local acceptance is an open question. Alternatives like hydrogen trucks, synthetic fuels or liquefied natural gas exist and have to be analysed in more detail. If trolley trucks should be implemented policy action is desired and should be started in time due to the necessary time to market.

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Building scenarios for climate change mitigation and adaptation for urban transport in Delhi, Mumbai and Bangalore

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Overview

This paper present result from the research project CLIMATRANS on scenarios for climate change mitigation and adaptation for urban passenger transport for mega cities in India with case cities Delhi, Mumbai and Bangalore. The contribution of urban areas, in particular mega cities, to the rapid economic growth in India has been significant. The economic growth and the contribution of the urban settlements to the growth is expected to continue in the coming years. The population of mega cities in India have been growing rapidly putting further pressure on urban transport infrastructure as well as increase in contribution of the transport sector to the GHG emissions and emissions of local air pollutants. Meanwhile, there has been an increase in occurrences and severities extreme climate events affecting urban areas. These trends have important consequences for mitigation and adaptation scenarios for mega cities in India. The research recognizes that the scenarios for mitigation and adaptation should be integrated.

India an important signatory to the 2015 Paris Climate Accord 2015. India has committed to reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level (India's Intended Nationally Determined Contribution: Working towards climate justice, The Paris Agreement: A universal call to Action for Governments and Businesses; What it Means for India). There has been significant decrease in costs of renewable energy and storage and potentials for electrification of the urban transport systems in India. By 2050 India could significantly outperform its commitments under the Paris Agreement.

Method and data

A multi-disciplinary and multi-theoretical approach (incl. meteorology, economics, geography, sociology, and political science) is used for the construction of scenarios for climate change mitigation and adaptation for urban transport for the case cities Delhi, Mumbai and Bangalore. In addition, the research takes a stakeholder perspective at the case city and national levels. The research focuses on five broad areas of analysis:

- Past trends and current situation
- Outlining of trends up to 2030 and 2050
- Scenario construction and analysis
- Scenario evaluation
- Identification of institutional and other barriers for implementation

Past trends and current situation focus on variables that affects demand for transport such as population, economy and economic growth, changes in land use, transport infrastructure, motorized and non-motorized mode shares, etc. It also examines the past trends on the occurrences of extreme weather (rainfall and temperature) as well as areas susceptible to flooding.

The future trends of exogenous variables that influences demand for transport are based on past trends as well as other auxiliary data. The data is used for the development of transport model systems for the 3 case cities as well as prediction of demand for travel by modes under a base (business as usual) scenario and different policy scenarios for mitigation and adaptation for each case cities.

The predictions of occurrences of extreme weather (rainfall and temperature) relies on past trends and Climate Scenario RCP 8.5. The results are used for the development of flooding models Mumbai and Bangalore and Delhi. Climate Scenario RCP 8.5 is also used for the predictions of CO2 emissions as well as emissions of PM2.5 and other pollutants from passenger transport in the case cities for the base scenario as well as policy scenarios for mitigation and adaptation. The emissions of pollutants are converted to concentrations. WHO is used for the calculation of mortality due to PM2.5 concentrations.

Identification of policy packages for mitigation and adaptation scenarios are based on an expert DELPHI study and consultations with each case city stakeholders. Each case city has constructed 3 to 4 policy scenarios. The policy scenarios for the case cities differ due to their transport system particularities and their transport plans. Electrification of the motorized modes under different energy mix has been added to these scenarios.

Results

The base scenarios and different policy scenarios are calculated up to 2050 for each case city. The evaluations are based on CO2 emissions and emissions of local pollutants from the urban passenger transport sectors, the concentration of PM2.5 and consequences for health impacts as well as land use susceptible to flooding. The calculations of CO2 emissions and emissions of local pollutants are based on modes of transport, passenger vehicle kilometers and emission factors by modes. The results of the evaluations of policy scenarios for mitigation and adaptation are reported in the CLIMATRANS final reports for Delhi (2018), Mumbai (2018) and Bangalore (2018). All policy scenarios for the case cities meet the overall India's Government for the GHG mitigation. The paper presents the rankings of the policy scenarios for each case city.

Conclusion

We highlight a few conclusions of the research:

- The ranking of the policy scenarios for the 3 case cities points to the importance of the transport system particularities and existing transport plans.
- All policy scenarios for the 3 case cities meet the overall India's objective for the reduction of the GHG emissions.
- The results point to the importance of integrated land use and transport policies for mitigation and adaptation.
- Electrification of the urban passenger transport system result in significant health benefits. However, the emission of CO2 depends on energy mix. If electricity is produced from non-renewable sources, for example coal, there will be an increase in the emission of CO2 compared with other policy scenarios.

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CLIMATRANS final report for Delhi. (2018), Principal investigator Professor Sanjay Gupta

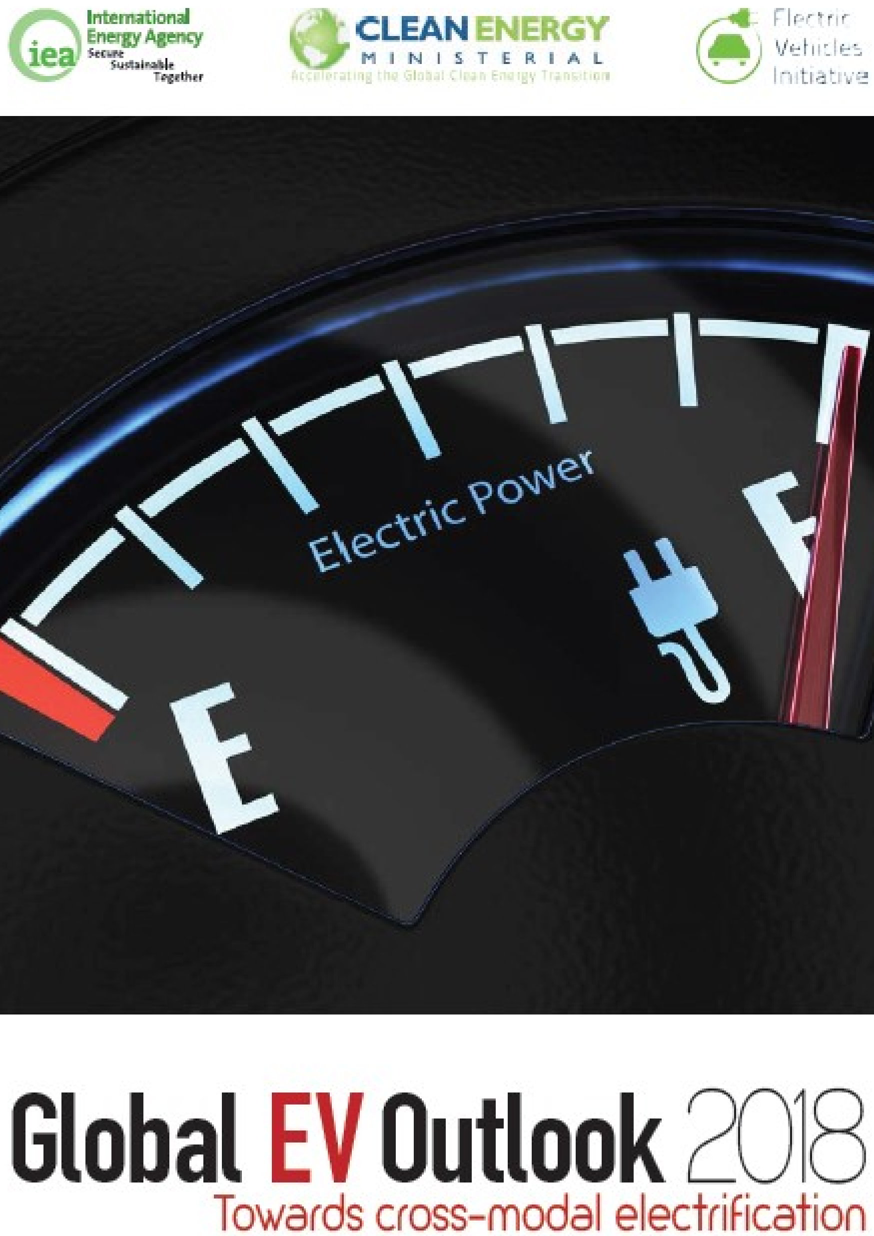
CLIMATRANS final report Mumbai. (2018), Principal investigator Professor Munish Chandel

CLIMATRANS final report and Bangalore. (2018), Principal investigator Professor Ashish Verma

Presentation of new insights from World EV Outlook 2018

Jacob Teter, IEA

Jacob Teter joined the IEA as an energy analyst in 2015. His primarily responsibilities to date have been to expand and refine modelling capacities and conduct analysis for the IEA Mobility Model (MoMo) to contribute to Energy Technology Perspectives 2016 and other IEA publications. He received his doctoral thesis focusing on the impact of water use on energy supply pathways, with a focus on biofuels and electricity generation from the University of California, Davis in 2015. Jacob enjoys learning about the wonders of coding (C, python, and R), GIS analysis, and in his “off-screen “life he likes to cook, hike, and bike.



Key Note 2: Mitigating transport emissions by encouraging non-motorised transport

Eva Heinen, University of Leeds

Eva is a transport research scientist with an interest in travel behaviour change. She studies individual travel behaviour: Why people travel, where they travel to, and particularly which transport modes they use. In her research she seeks to test causal relationships and employ a variety of research methods, both quantitative and qualitative.

Eva has experience with longitudinal data collections and analyses, natural experimental studies and international qualitative research. She has published a wide variety of papers with co-authors from all over the world in transport, public health, and urban planning journals. Her research is empirically driven and combines different fields including transport, public health and urban planning.

Background and experience

Eva joined ITS as an University Academic Fellow in October 2015. Before that she worked at the University of Cambridge in the Medical Research Council (MRC) Epidemiology and Center of Diet and Activity Research (CEDAR), as well as Delft University of Technology where she held a prestigeous fellowship of the Dutch Research Council (VENI) on travel behaviour change. Prior to that she was an Assistant Professor of Infrastructure Planning and Mobility at the Department of Spatial Planning & Environment at the University of Groningen. She received her PhD on the topic of 'Bicycle commuting' in 2011 from Delft University of Technology and continued working there as a researcher. Before her academic career, she worked at the Ministry of Housing, Spatial Planning and the Environment in the Netherlands, the Netherlands Institute of Spatial Research (RPB) and the Transport Department of the Dutch Embassy in Berlin.

Eva is involved in international scientific networks and organizer/co-organizer of paper reviews and programming for two major conferences (WCTR & TRB). She is a member of the 'Bicycle Committee' and the ' Small and Medium Sized cities committee'. TRB is the largest transport conference in the world with more than 5,000 presentations in over 800 sessions and workshops and attended annually by more than 13,000 participants. She is the co-Chair of the paper and presentation subcommittee of the bicycle committee since 2011 and coordinates a group (4–10) review coordinators in an annual review process. She is also the chair of the Special Interest Group of the World Conference on Transport Research (WCTR) of Topic Area F4 Non-Motorised transport and Liveability.

HOW TO DECARBONIZE THE TRANSPORT SECTOR IN FRANCE?

Review of prospective scenarios to 2050

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Overview

In order to keep global warming below 2°C, France set itself the targets of dividing its greenhouse gas emissions by a factor of 4 between 1990 and 2050, and reducing the transport emissions by at least 70% between 2013 and 2050. Furthermore, the new carbon neutrality goal for France by 2050 requires to consider this last figure as a minimum. The presentation aims to shed a new light on this challenge, based on the multiplicative decomposition of CO_2 transport emissions into five key drivers: transport demand, modal shift, vehicule load factor, energy efficiency and carbon intensity of the energy. Firstly, a descriptive approach from the comparison of 27 prospective scenarios for transport in France is presented, highlighting the measures related to these drivers and the difficulty to reach the objective, as only half of the pro-active scenarios on energy transition reach the contribution to the "Factor 4". Secondly, a Kaya identity adapted to the transport sector is used to decompose the past trends of transport emissions into these five factors, showing the determinant role of transport demand in this evolution. Finally, this same multiplicative decomposition is applied for some prospective scenarios to 2050, indicating the strong expectations for the decarbonisation of the energy mix (carbon intensity) for the technology-oriented scenarios, and the important behavioural changes in terms of sobriety and modal shifts for the mobility- or demand-oriented scenarios.

Methods and Data

The study aims to inform the possible paths to meet the objective of Factor 4, on the basis of a comparison of 13 papers including 27 prospective scenarios related to energy transition or transport to 2050 (Bigo, 2016; ADEME, 2017; IDDRI, 2017; négaWatt, 2017). The scenarios hypothesis are classified in five CO_2 emissions drivers: to moderate the transport demand; shift to efficient transport modes; increase the occupancy rate of vehicles; improve the energy efficiency of vehicules; and to shift to less carbon intensive fuels. The resulting impacts on CO_2 emissions of the transport sector are then compared.

Besides this descriptive analysis of the scenarios, a quantitative one is realized by using a decomposition analysis of the transport CO_2 emissions (in the same form as the Kaya identity, the Log Mean Divisia Index; Ang, 2004), into the 5 multiplicative factors identified above: transport demand, modal shift, occupancy rate, energy efficiency of the vehicules, and carbon intensity of the energy. This decomposition is applied both to past trends and to some of the 27 studied scenarios, when sufficient data is available to do so.

Results

From the comparison of the prospective scenarios, a typology of the 27 scenarios is proposed: it identifies 8 trend scenarios and 19 pro-active scenarios on energy transition, of which 17 have assumptions that are mostly endogenous to the transport sector. These 17 scenarios are then classified according to their main driver, whether it is public policies, technical evolutions or mobility behaviours. It appears that only half of the pro-active scenarios reach the transport contribution to the "Factor 4", illustrating the difficulty of this goal and then the necessity to combine the five evolutions to reach this ambitious objective.

Furthermore, the quantitative approach through the use of the Kaya identity allows to understand the main factors driving the evolution of CO_2 emissions in the recent decades. This background allows to to better identify and compare the necessary breaks with the expected progress in the prospective scenarios.

Abstract Submitted to World Conference of Transport Research Society' Conference on
Transport, Climate Change and Clean Air in Paris 2018

The past trends show a growth in CO_2 emissions from 32 to 125 $MtCO_2$ between 1960 and 2015, after a peak at 135 $MtCO_2$ in the early 2000s. This trend is explained mainly by the increasing transport demand and modal shift towards road transport both for passenger and freight transport, before an inversion of these factors at the beginning of the 2000s. The occupancy rate decreased for passenger cars (thus participating in the CO_2 emissions growth) but the loading rate increased for road freight (more tons are transported by vehicle), whereas energy efficiency participated regularly in the emission reduction, and the impact of the carbon intensity of the energy was marginal on the global period.

This last point contrasts with the energy transition scenarios that rely highly on the decarbonization of the energy mix to achieve the emission reduction target. At the same time, the ambitious scenarios obtain a deep reduction in the transport energy consumption, until a division by 3 for some of them, by limiting transport demand, reducing the modal share of road and air transport, and improving both the occupancy rate and the energy efficiency of the vehicles. The study gives orders of magnitude of these relative contributions for some scenarios, which depend highly on the priority the authors view between technological progress (for energy efficiency and carbon intensity) and more demand-side changes (transport demand, modal shift and load factor).

Conclusions

The presentation focuses on the means to reach the objective of reducing by 70% the transport CO_2 emissions in France by 2050. The contribution is threefold: a descriptive comparison of scenarios is used to identify the key assumptions and the resulting emission reductions; secondly, a quantitative assessment identifies the contribution of five factors explaining the past evolution of transport CO_2 emissions; finally, these recent decades evolutions are compared to an application of this methodology for some French transport scenarios by 2050.

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Is Hyperloop helpful in relieving the environmental burden of long-distance travel?

An explorative analysis for Europe

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Overview

Long-distance travelling accounts for a significant and increasing part of the mileage of person travel and the respective environmental impacts (Van Goeverden *et al*, 2016). Energy consumption and emissions connected with long-distance travelling might be substantially reduced through use of evacuated tubes of low air resistance, such as the recently proposed Hyperloop transport system (HL). This paper explores the extent to which a fully developed HL network system in Europe could reduce energy consumption and GHG emissions of long-distance passenger transport.

Methods and Data

The analysis includes two main stages: a calculation/estimation of the energy consumption and CO_2-emissions of the HL mode; and a forecast of the impact on travel demand. The latter includes both the design of an HL network which defines the service level and the capacity of the HL mode, and the estimation of the (potential) demand; the actually transported demand can be lower than the potential demand because of capacity limitations.

The energy consumption is calculated both for the HL vehicles movement and for the life-cycle of the HL project, assuming a cruising speed of 1200 km/h and an acceleration and deceleration of 1.5 m/s^2. The energy consumption of HL vehicles is strongly negatively correlated to the distance between stops, because a significant part of the consumption is for acceleration and deceleration. The calculated consumption, expressed in kWh/seat km, is 0.1 for 200 km, 0.036 for 600 km, and 0.025 for 1000 km distance between stops. The additional energy consumption for the life-cycle of the HL project is likely to be significantly higher; we assume roughly 500 kJ/seat km, somewhat more than that for railways. The limited freedom in the routing of HL lines due to the very wide curves may require to build a significant part of the network in tunnels below the earth surface and this could consume a relatively large amount of energy.

The CO_2-emissions related to HL vehicles depend on the source of electricity used. The initial HL proposal involves solar cells on the tube that could produce all required energy for vehicle movement (Musk, 2013). In this case, the CO_2-emissions would be zero. However, this is not possible for tunnelled parts of the network. We assume two variants of the HL system, one with zero emissions and one where a significant part of the network is tunnelled and where the emissions (in gram) are calculated by multiplying the energy consumption in MJ with the factor 70, which is the (rounded) conversion factor for fuel. The same factor is used for the emissions related to the additional energy consumption for the life-cycle.

The defined HL network consists of links between the European cities that have a population of at least 500,000 inhabitants. Lines in the network may cross important physical barriers in the case the barriers currently are crossed by railway lines or roads (like the Alps or the Channel). There are no links to more remote isles like the Canary Isles and no intercontinental links, except for links between Europe and Turkey. The density of the designed network is 0.01 km/km^2, the average distance between stations is 300 km. We assume that the services do not stop at each station and that the average distance between stops is 600 km.

The impact of the introduction of a HL system on travel demand includes both shifts from other modes to HL and induced demand. We made a forecast of the two impacts for the year 2025. At first, the total long-distance travel demand is estimated for 2025. The estimation is based on the microdata of the Dateline-project, a survey of long-distance travelling of the residents of 16 European countries conducted in 2001/2002, tourist statistics, statistics of Eurostat on long-distance travelling, and published expectations about future trends (e.g. EC, 2013). The analysis is limited to the travel demand of the residents of the Dateline countries that include nearly all Western-European countries but exclude most of those located in Eastern Europe.

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The potential shift from alternative modes to the HL is estimated by assuming different shift factors based on travel times, travel costs/fares, and typical modal qualities. The HL mode is assumed to have the most competing travel times for long trip distances and for origins/destinations that have over 500,000 inhabitants. Travelling with HL is likely to be expensive (Van Goeverden *et al*, 2017) making the system relatively unattractive for leisure travellers. With respect to the modal qualities, the HL is assumed to be most competitive to the other public modes (train and airplane). Private modes (e.g. car, bus chartered for group travel) have special qualities like avoiding access/egress trips, availability of the mode at the destination, and a lot of room for luggage (car).

The estimation for induced demand is based on the observation that no correlation seems to exist between speed of the transport system and travel time (Schafer, 1998). In that case, the induced+shifted trip kilometres are equal to the product of the relative reduction in travel time (ratio of the door-to-door travel times by the original travel mode and HL) and the shifted kilometres to HL. We assume that the induced kilometres are two times the shifted kilometres from the relatively slow land modes and 30% of the shifted kilometres from the much faster airplane.

Results

The estimated demand for HL exceeds by far the capacity. The calculated capacity is 180 billion seat km in the whole continent, and 115 billion seat km in the Dateline countries. The forecasted person km by HL is in the order of 500 billion. This means that either the capacity has to be enlarged by building parallel lines for accommodating the potential demand, or the transported demand will be limited to the low capacity. We analysed both variants. In the case the capacity is not enlarged, we assume the fares of HL being raised to the level where capacity and potential demand are balanced. The higher fares will particularly reduce the leisure travel segment, which is by far the largest segment of the long-distance travel market. Additionally, we assume no induced demand in the case the capacity is an important bottleneck and the fares are extremely high.

The estimated reduction of energy consumption of long-distance travelling as the result of HL introduction is 3.1% in the case the capacity is enlarged, and 1.8% if capacity is a serious bottleneck and the fares are raised. The values for the whole life-cycles are smaller: 0.2% and 1.3% respectively. The reductions of the CO_2 emissions are close to those for energy consumption, except when zero emission for HL vehicle movement is assumed; in that case the reductions are about 2 and 0.4 percentage points larger for the variants with and without sufficient capacity. With reference to the smaller travel market of long-distance trips inside the area served by the HL network, the reductions in terms of percentage are about a factor 1.7 larger.

Conclusions

A Hyperloop transport system will likely reduce the energy consumption and emissions of long-distance person transport, but the reduction will be small, just a few percent. Considering the whole life-cycle, the reduction is negligible. The HL is not more energy-efficient than train or bus and competition with these modes will increase the total energy consumption as the consequence of induced demand. The total, favourable impacts are the balance of an increase of energy consumption caused by the competition with train and bus, and a larger decrease caused by the competition with airplane and car. The impacts can likely be increased by designing a HL network that provides only services on routes where currently the airplane is the dominant mode.

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Barriers to the implementation of climate mitigation and adaptation policies: A case study of Delhi, Mumbai and Bangalore

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Overview

Cities, and particularly megacities, play an important role in India's economic growth – more than 60 per cent of the Gross Domestic Product (GDP) is produced in urban areas (Singh, 2016). This paper focus on India's three largest cities: New Delhi, Mumbai, and Bangalore. The population of these cities have been growing rapidly, posing immense pressure on the infrastructure including transportation, sewage and drainage systems. These cities face similar transportation related problems - traffic congestion, increasing GHG emissions and serious air pollution. They face massive challenges to mitigate transport emissions as well as adaptation to extreme weather due to climate change.

As several scholars (Revi, 2007; Ahluwalia and Mohanty, 2014) have recognized, there are significant institutional barriers for optimal design of policies and interventions. Different policy instruments are often under the control of different agencies or even different levels of government, and their actions are not or cannot always be coordinated. Furthermore, optimal application of policies and measures involves financial costs, and governments at all levels are subject to severe budgetary constraints.

Analytical perspectives, method and data

Analytical perspectives on policy barriers are derived from theoretical contributions in political science. Whether a policy instrument, or a package of policy instruments, will be implemented depends on institutional capacity and whether it has sufficient political and cultural acceptance. Barriers to implementation can therefore be understood as any kind of factor that impede or hinder policy adoption and/or implementation of single policy measures or policy packages (Olsen and Fearnley, 2014).

May et al (2003) identifies four broad categories of barriers:

1. Coordination issues, legal and institutional barriers
2. Financial barriers
3. Political and cultural barriers
4. Practical and technological barriers

A policy instrument, or a package of policy instruments, will induce particular political, institutional, communicative, and other barriers that are country specific. The paper examines the institutional framework for urban transport in India as well as the particularities of Delhi, Mumbai and Bangalore.

Qualitative data were collected in 2017 using semi-structured interviews with stakeholders at national and the case city levels. The interview guide was the implementation of specific measures and barriers/ opportunities for implementation. Because the three cities have different challenges, the measures we asked about somewhat differed, depending on the city or government level. We also used insight from a Delphi-study, conducted in 2016. The Delphi study was conducted as a two round survey, with responses from experts in New Delhi, Mumbai and Bangalore.

The collected data on climate mitigation and adaptation policies are analysed within the institutional frameworks for urban transport Delhi, Mumbai and Bangalore.

Results

Climate policy measures are diverse, including integrated land use and transport planning, and mitigation and adaptation policy measures. All categories of measures include actors and stakeholders from various sectors, potentially involving challenges of vertical and horizontal coordination. The table below summarizes main elements of the climate mitigation policy measures. The main elements of climate adaptation policies will be provided in the paper.

	Type of policy	Barriers, Delphi	Barriers, interviews
Information technology for traffic management	Majority	Institutional and Political	Funding, Technological issues, political will, the fragmented institutional framework
Electronic congestion pricing	Entrepreneur	Institutional and Political	Political will, the quality and legitimacy of public transport
Electric vehicles	Entrepreneur	Technological and Economical	Practical and financial barriers, energy source for electricity
Freight restriction policies	Entrepreneur	Institutional, Political & Economic	Establishment of by-passes
Bus Rapid Transit	Client	Not examined	Connectivity to other transport modes, road space
Metro Rail Transport	Client	Not examined	Social acceptance
Public Private Partnership	Client	Not examined	Outlining adequate contracts, costs for users
Car Sharing	Interest group	Cultural	Inconvenience of sharing your car, regulation and incentives

Conclusion

A summary of the conclusions is:

- Combine measures into policy packages
- Integrate mitigation and adaptation policies
- Strengthen vertical and horizontal coordination
- Strengthen institutional competence
- Strengthen the local level of decision making
- Promote public private partnership

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Impact of Climate Change on Mobility of Urban Poor Dwellers in the Yamuna River Floodplain: Case study of Delhi, India

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Transport is an important contributor to the well-being of individuals and communities because it is a means by which people can improve their quality of life. Lack of suitable and affordable transportation can be a significant barrier to participation for different groups within society. Transport is relevant to social exclusion because those without access to transport have difficulty in accessing employment, education, health and other services (UN-Habitat.2011). Transport Accessibility is important not only for its role in facilitating regular and stable income earning employment, but also as a part of the social capital which maintains the social relations forming the safety net of disadvantaged communities in many societies. The transport disadvantaged sections of society constitute significant share in Delhi city's population (GNCTD.2009) and have to make considerable physical effort and spend a large amount of time to gain access to source of income, health and educational institutions. Empirical studies carried out in India on mobility levels reveal that transport disadvantaged sections comprising poor, aged, women, children and physically challenged people often due to lack of an efficient urban transport system are constrained in meeting their mobility requirements thereby denying them the access to potential opportunities which could enhance their quality of life (World Bank. 2009).

An emerging dimension of research in developing countries from equity perspective is the impact of climate change in transport sector and its impact on mobility levels of urban poor. Perpetual emphasis on urban mobility, primarily for private vehicles, coupled with other socio-economic factors, has resulted in Delhi's vehicle population to increase exponentially leading to increasing contribution of greenhouse gas emissions from transportation sector. The study is grounded in spatio-temporal empirical analysis for four time periods - 1986, 1996, 2006 and 2016. Data in the study has been collected from online geoportals of United States Geological Survey (https://www.usgs.gov/), Bhuvan (http://bhuvan.nrsc.gov.in/bhuvan_links.php) and Government of NCT of Delhi, to assess the trends of climate change in the city. Accompanying this population and spatial change in city's urban expanse, climate of the city in terms of its temperature and precipitation has also changed. From 1901, the city's annual average temperature has increased by 1.4ºC, with an increase of 0.93 ºC in the past four decades. In 2015, almost half of the city was inundated within 3 hours of rainfall, affecting localized areas as well as travel pattern in terms of congestion and travel time.

The present paper is based on an empirical study carried out for urban poor dwellers residing in habitations in the floodplains of river Yamuna in Delhi, capital city of India. Preliminary findings of the field studies reveals that over 70 per cent of its working male work within 5 to 10 kilometer radius from their settlement, while over 85 per cent working female are employed as domestic help within 500 meter radius. For accessing education and commercial facilities, villagers travel to as far as 2 kilometers, while for medical facilities over 65 per cent cases are dealt within 1 kilometer range at local nursing home and dispensary. Owing to floods in Delhi due to climate change phenomena and the resultant loss of connectivity there is productivity loss for case study workers in terms of 7 to 12 working days which further results in lose over 23 per cent to 50 per cent in their monthly income.

These multifaceted interlinkages between urban development, climate change and their cumulative repercussions on urban mobility for the city and its vulnerable population, calls for climate resilient urban planning strategies for development of the capital, with a dire need to focus on climate carrying capacity based urban future.

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A COMPARISON OF EMMISIONS OF CO_2, LOCAL POLLUTANTS AND HEALTH IMPACTS OF MITIGATION TRANSPORT POLICY SCENARIOS IN THREE INDIAN MEGA CITIES

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Overview

Climate sensitivity augmented by a large and rapidly growing population and huge complex transport systems makes India a vulnerable country in terms of climate change impacts. It is thus evident that India is an important country to study in terms of both the transport sector's contributions to global climate change and the projected future climate impacts for India; and which strategies that can be implemented to bring down emissions and promote sustainability. These are also global issues affecting other parts of the world, both in a short and long-time horizon.

This paper summarizes the main findings of the evaluation of alternate mitigation strategies for the passenger transport sector in the three case cities Delhi, Bangalore and Mumbai in the Indian-Norwegian research project CLIMATRANS. The main objectives of the project are: 1) Assess climate change and environmental impacts in urban areas in India related to the transport sector. 2) Develop mitigation and adaption strategies related to the transport sector in urban areas in India. The project is supported by the Norwegian Research Council over a period of four years, and is led by the Institute of Transport Economics in Oslo. The research work in India has been conducted by local expert academic research teams. The main focus in this paper is on comparisons of estimations of transport-related emissions and related health effects under different policy scenarios. Mitigation policy packages, have been formulated for each of the three case cities. For each case city evaluations of the Business as Usual (BAU) scenarios and different mitigation policy strategies (policy packages) have been performed, with and without electrification of transport. This paper provides an overview of the main results from the policy evaluation, and highlights the mitigation strategies (policy packages) that appear to be the most effective to reduce CO2 emissions and improved health impacts compared to the BAU scenario in the three case cities.

Methods and Data

The research approach has been as follows: Climate effects of estimated emission levels have been assessed through downsizing of the Climate Scenario RCP 8.5 for 2030 and 2050 to adjust it to the grids that correspond to the case cities' transport networks. Then rapid assessments of the emissions of CO_2 and other pollutants in 2030 and 2050, given a continuation of current policies (BAU scenario) has been made for each case city. Alternate policies for each city has been identified through stakeholder workshops and an expert Delphi study. Different policy packages have been formulated for each case city, with case city transport system characteristics and transport plans taken into consideration. Through the use of transport demand models, emission factors have been applied to the estimated future travel demand of the various transport modes to arrive at total emissions for BAUs and policy packages in each case city. In addition, since electrification of the transport sector shows promising prospects in all cites, four different energy source scenarios have been developed to estimate the effects of implementing electric mobility (EVs) given different mixes of non-renewable and renewable energy sources.

Lastly, health effects expressed as mortality numbers have been estimated for each case city based on emissions of ultrafine $PM_{2.5}$, which is considered among the most dangerous pollutants to human health (The Lancet Commissions, 2016). First, data on the number of mortalities in the case cities due to $PM_{2.5}$ air pollution in the base year 2011 have been etablished, and projections for 2030 and 2050. Then transport's share of emissions has been collected from various reports estimating the share. Annual emissions of $PM_{2.5}$ in tonnes per year has then been calculated for 2011 for the case cities. Assuming transport's share of emissions is equal to transport's share of mortalities, the number of mortalities in each case city was calculated. Assuming a reduction in mortalities is proportional to the reduction in $PM_{2.5}$ emissions in horizon years 2030 and 2050 in the case cities. Finally, the number of annual mortalities was estimated based on the estimated $PM_{2.5}$ emissions under the BAU and policy packages for each city. Emissions related to the production of electricity are not considered to influence health effects since the production of electricity and related emissions are located outside the case cities' boundaries.

Results

For Delhi, the greatest reduction in CO2 emissions can be achieved by implementing Policy package 3 (descriptions of policy packages are provided in the paper). This is a combination of Policy package 1 with electric mobility, reducing CO_2 emissions from 3.0 million tonnes of CO_2 emissions per year in 2030 under the BAU, to 1.7 million tonnes with this combination of policy package. For 2050 the reduction is even greater, from 5.1 million tonnes to 1.9 million tonnes.

For Bangalore, the impacts of the policy package on total emissions are less pronounced. The better among the policy package (Policy package 2, PP2) slightly outperforms the BAU for 2030 in terms of reducing CO_2 emissions, with 1.8 million tonnes of CO_2 emissions for PP2 compared to 1.9 million tonnes in the 2030 BAU. Similarly, PP3 yields slightly lower CO_2 emissions for 2050 than the BAU in Bangalore.

The BAU and policy package evaluations for Mumbai identify Policy package 2 (PP2) as the "best" compared to the BAU considering CO_2 emissions. With implementation of PP2 for Mumbai CO_2 emissions are estimated at 5.1 million tonnes of CO_2 vs. 5.6 million tonnes in 2031 (BAU). In 2050, emissions of CO_2 are estimated to have risen to 13.3 million tonnes of CO_2 under the BAU, compared to 12.4 million tonnes for PP2 for Mumbai.

In Delhi the estimated reductions compared to the BAU in 2030 is 58% through implementation of the best policy package and uptake of electric mobility under the 100% renewable power source scenario no. 4. In 2050 the reductions are estimated to be as much as 82% in Delhi. In 2030 in Mumbai the CO_2 emissions can be lowered by 31% through implementing the best policy package combined with electric mobility, and in 2050 the emissions can be 45% lower. Lastly, in Bangalore CO_2 emissions can almost be eliminated with the best policy package and electric mobility, with only 0.03 million tonnes of CO_2 in 2030, which is a 98% reduction compared to the BAU. In 2050 the reductions are even bigger in absolute terms, with emissions estimated down from 3.3 m. tonnes to 0.03 m. tonnes, a 98% reduction.

Mortalities in 2050 when implementing the best policy package in Delhi only represent about 11% of the moralities estimated under the BAU. In Mumbai, the estimated number of mortalities is only about 52% of the BAU estimates, and in Bangalore the number of deaths are only 32% of the corresponding BAU estimate for 2050.

Conclusions

In conclusion, the different policy packages have varying impact on the different types of emissions compared to that of the BAU in all cities, but in general most of them will bring down the emissions compared to the BAU. For both Delhi, Mumbai, and Bangalore a larger scale conversion of the vehicle stock into electric vehicles will by far have the greatest impact on CO_2 emissions for both horizon years, compared to that of the BAU. In particular, this is the case when EVs are combined with the "best" performing policy package, comprising Policy package 3 for Delhi and Policy package 2 for Mumbai. For Bangalore, the differences on emission impacts of the policy package vs. the BAU are small to marginal in some cases. When incorporating electric mobility in Policy package 4, however, the results are much more pronounced also for Bangalore.

However, the positive impacts of the introduction of EVs and electric mobility are highly dependent on the power source for the electric vehicles, whether it is from renewable or non-renewable sources. In some cases, utilizing electricity from non-renewable (fossil-based) power sources can have little positive impact terms of CO_2 and other emissions. Notwithstanding, the power source mix scenarios show that just a modest introduction of renewable power sources can have profound positive effects.

Air pollution represents a serious problem in India's megacities, and in this paper we have considered the estimated effects of $PM_{2.5}$ emissions by the transport sector (i.e., tailpipe emissions) on mortality in the future. Even though one can expect a great drop in mortality rates attributed to $PM_{2.5}$ emissions due to other factors than implementing the suggested policy packages, these policy package will, however, have a significant effect on reducing mortalities even further. This is particularly the case when including policies that will increase the share of electric mobility/vehicles. In addition to other very positive effects on e.g. GHG emissions and pollutants, these policy package can potentially save many lives per year in the future in Delhi, Mumbai and Bangalore.

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PUSH EV DEMAND OR SUPPLY?

Evaluating zero-emissions vehicle policy in Canada

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Overview

Research and real-world experience demonstrate that strong policy can encourage plug-in electric vehicle (PEV) sales to approach the levels needed to meet long-term greenhouse gas targets. Globally, we can see that the regions with the strongest PEV supportive policies—Norway, the Netherlands, and the State of California—also have the highest PEV new market shares (Mock and Yang 2014; Sierzchula, Bakker et al. 2014; Melton, Axsen et al. 2017). In this paper we explore and compare PEV purchase incentives and sales mandates in their ability to induce substantial PEV sales. In particular, we focus on the goal of PEVs accounting for at least 30% of new light-duty vehicle sales by 2030, as set by the Clean Energy Ministerial in their "EV30@30" campaign, organized by the International Energy Agency (2017). Specifically, our present research objectives are to simulate:

1. the effects of Canada's current suite of climate policies on 2030 PEV new market share;
2. the stringency and duration of financial incentives needed to meet the 30% by 2030 target (and required government expenditure); and
3. the feasibility of automakers' compliance with a ZEV mandate requiring 30% or 40% PEV new market share by 2030 (with some supportive policies in place).

Methods and Data

To explore the feasibility of this goal, we use a behaviourally-realistic vehicle adoption model (REPAC, see Figure 1) to simulate the impacts of incentives and vehicle mandates to on PEV sales over this time frame, using the case study of Canada. The model is documented in full by Wolinetz and Axsen (2017). We consider a range of technology assumptions, including optimistic and pessimistic battery cost scenarios ($CDN 85/kWh and $CDN 125/kWh, respectively, by 2030).

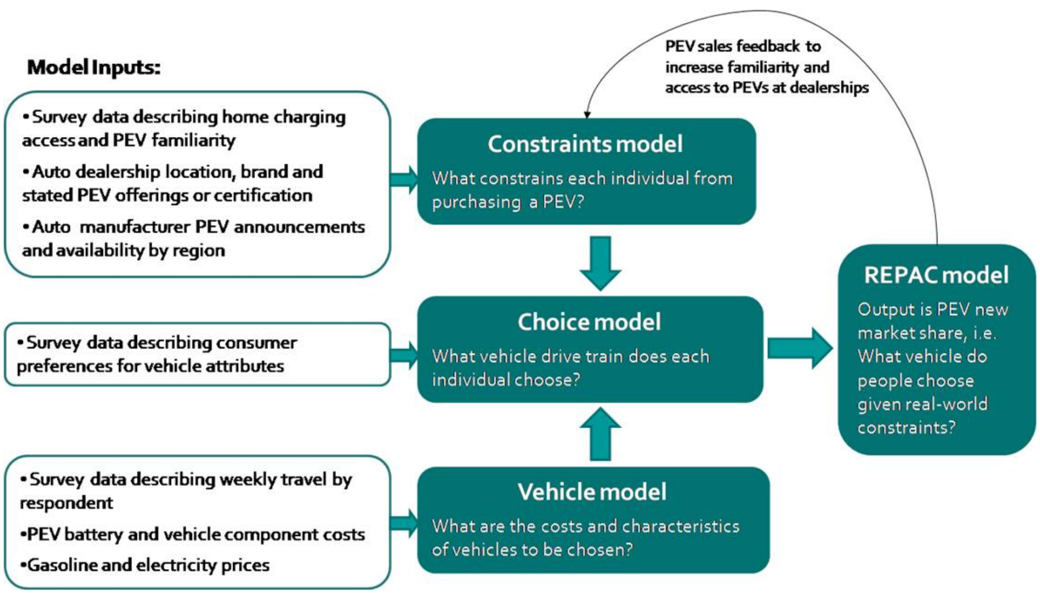

Fig. 1: Structure of the REPAC PEV market share simulation model,

Results

We find that the country's present policies can only induce PEVs to reach 5-11% new market share by 2030 (Figure 2). Without changes in PEV supply, we find that purchase incentives can boost PEV new market share, where a $CDN 6000/vehicle subsidy is needed for 13 years to reach the 2030 goal (in the median technology assumption scenario).

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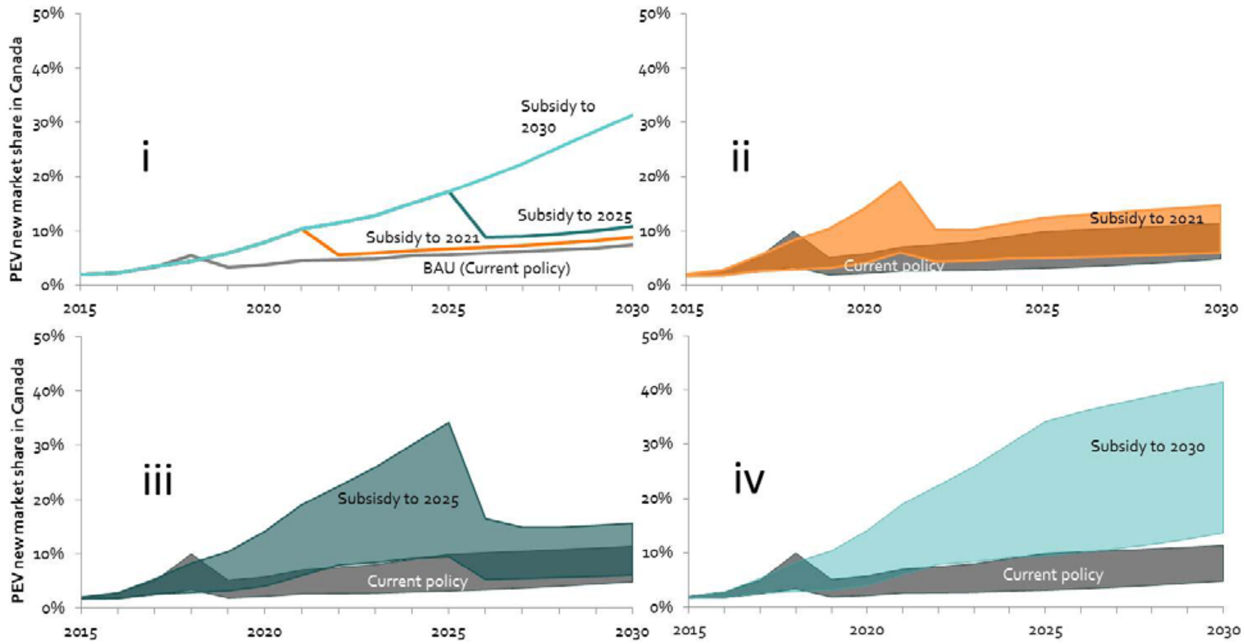

Fig. 2: PEV new market share under BAU and demand-focused policy scenarios (i is single point estimates for the reference scenario, and figures ii, iii and iv include shading to represent uncertainty in the PEV familiarity constraint, the PEV availability constraint, gasoline price and PEV purchase price)

We also model ZEV mandate scenarios where automakers must reach 30% or 40% PEV sales by 2030, finding that compliance with both is achievable even in pessimistic technology scenarios, through a combination of increased PEV drivetrain availability and intra-firm cross-price subsidies (not shown here). While incentive-based or mandate-based strategies (or some combination thereof) can achieve 2030 goals, results demonstrate the high government expenditure involved in an incentive-based strategy -- $CDN 15-48 billion undiscounted ($10-28 billion discounted), or around $9,000-10,000 per added PEV sale.

Conclusions

Present policies are not sufficient to meet long-term sales goals. These goals can be met by incentive-based or mandate-based strategies, though the incentive-based strategy is more uncertain and more costly for government. Policymakers ought to consider these tradeoffs, among others, when designing PEV-supportive policies to achieve long-term climate goals.

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E-MOBILITY ADOPTION PATHWAYS IN FRANCE, GERMANY AND NORWAY

Comparative analysis of macro-environmental factors for knowledge transfer and best practice identification

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Overview

This work's aim is to provide a comprehensive review of all factors affecting electric vehicle (EV) adoption in representative markets to show how these influence the electric vehicle adoption path. The scope of this work is not just to provide a comprehensive analytical framework for adoption path analysis but also to use it to investigate particularly informative European countries. Comparing the factor's implementation with the adoption path provides insights into their relevant interactions. This understanding contributes to contextual best practice identification for countries undergoing - and willing to improve - the adoption of electric vehicles. Such a knwoldge transfer oriented work has been proposed by (Altenburg et al. 2016). It is based on the comparison of the French, German, Chinese and Indian intial conditions and technological developments. The contribution at hand extends this approach with an analytical framework for the systematic and macro-environmental analysis of adoption pathways.
The paper is structured in six parts. The first section introduces the methodology, which requires the selection of informative countries based on their national adoption paths. It then motivates the choice of France, Germany and Norway and describes their adoption path as well as the political goals for their future evolution. The remaining sections each correspond to one of the identified macro-envrionmental adoption factors. In each of these sections, the selected countries are compared in terms of their chosen implementation. Impacts on the respective adoption paths are identified according to data situation.

Methods and Data

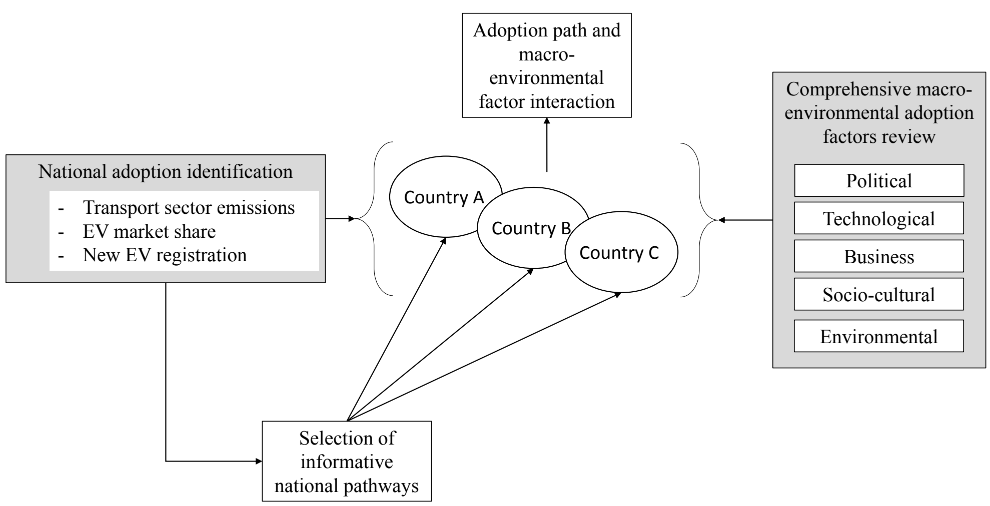

Fig. 1: Methodological approach

The chosen approach is a comparative analysis of macro-environmental factors and their influence on national adoption pathways for knowledge transfer and best practice identification. Given this framework, a selection of informative countries is made from a comparison of national adoptions in terms of EV market penetration, new EV registration and the transport sector's and new cars' greenhouse gas (GHG) emissions. The macro-environmental factors stem from a STEPE approach (socio-cultural, technological, economic, political, environmental analysis) and a literature review. The selected countries are compared to derive the influence of each factor on the national adoption path. This analysis is based on a literature review and data collection.

The methodology thus comprises a national adoption identification framework based on EV market penetration, new car registration and GHG emissions as well as a macro-environmental frame involving political, technological, business, social-cultural and environmental factors. Applying this framework requires four steps: (i) literature review to define the national adoption paths of a country panel, (ii) selection of informative countries, (iii) literature review and/or interviews to define the implementation of macro-environmental factors in the selected countries and (iv) comparison of the factors among countries to conclude about their influence on the adoption path.

Results

The paper analyses systematically the differences between France, Germany and Norway in terms of macro-environmental factors. Among these countries, Norway takes the leadership regarding EV adoption, followed by France and Germany. Regarding the market for EV production, Germany is currently the best-in-class country, closely followed by France. Norway has only marginal automaker industry (Hertzke et al. 2017).

Among the comprehensive set of macro-environmental factors some help explaining the differences in adoption paths among these countries. An abstract of the results is given here. France and Germany, as part of the European Union, have committed to limit the new cars fleet's GHG emissions, to a value of 95 g_{CO2} /km by 2021, whereas Norway has commited to a lower limit of 85 g_{CO2} /km by 2020, showing a stronger political willingness to reduce the transport sector emissions. Despite the same goal in new car emissions, France has set a more challenging goal of 2 million EV by 2020 on French roads, whereas Germany aims at 1 million local EV. As Germany is said to miss this goal (34,022 electric vehicles in 2016), the adoption path is thus not solely determined by political and regulatory goals. The social acceptance of car ownership is very different in France and Germany: whereas French users favour compact cars, German user prefer high-power cars with an additional function of a social marker. The german car industry is specialised in premium cars. In order to remain in the market, less wealthy French car makers entred the EV market in 2008 already (Altenburg et al. 2016). Moreover, Germany stopped researching and developing batteries in the 1970's while France continued (Altenburg et al. 2016).

This might explain the different pathes in EV production among these countries, but not necessarily the EV adoption differences. In this regard, the direct monetary incentives for EV acquisition show a clear correlation among the selected countries. (Tietge et al. 2016) shows that the direct incentives in Germany do not offset the higher price lists and taxes paid when buying an EV. In France, the direct incentive is higher than in Germany, but EV remain slightly more expensive than the same class internal combustion engine (ICE). In Norway, EV are cheaper than the equivalent ICE with current direct incentives. It is also worth noting that in 2016 the households paid 0.15 €/kWh, 0.17€/kWh and 0.30€/kWh for electricity in Norway, France and Germany, respectively. Norway has also a national plan for locally defined indirect incentives, whereas there is no equivalent in France and Germany. Added to the fact that France and Norway have national programs whereas Germany relies more on local and regional programs and showcases (Tietge et al. 2016), it seems that a simple and unified plan has a better impact on EV adoption. Not only fragmented incentives but also difficult to access information slow the EV adoption: as the interviews in (Ensslen et al. 2013) show, the range anxiety reduces when knowledge about available charging stations is reliable and easy to access. The relationship between charging infrastructure and EV adoption is not easy to define. First of all, it is a chicken-and-egg problem. Furthermore, (Blokhine et al. 2016) show that in the best performing countries the EV share and charging infrastructure correlate but in some countries, like Ireland, the high charging densitiy is accompanied by low EV share. Among the three studied countries the higher EV share, however, correlates with the higher public charging point density.

Conclusions

This work does not just provide a comprehensive analytical framework for adoption path analysis but also investigates particularly informative European countries. Comparing the factor's implementation with the adoption path provides insights into their relevant interactions and allows for best-practice and lock-in identification. This work thus helps reaching the goals set by countries in terms of EV share and GHG emissions in the transport sector.

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NETWORK TARIFF DESIGN WITH ELECTRIC VEHICLES AND DISTRIBUTED ENERGY RESOURCES

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Overview

Distributed Energy Resources (DERs), mostly in the form of solar PV and lithium-ion batteries, and electric vehicles (EVs) are emerging as three disruptive innovations in power grids. Recent studies have pointed out the potential synergies between these technologies (Mwasilu *et al.* 2014; Hoarau & Perez, 2018), while others have studied the difficulty to design adequate network tariff when consumers can adopt DERs (Eid *et al.* 2014; Schittekatte *et al.* 2018). In this paper, we fill gaps in both bodies of the literature by investigating the combined effect of DERs and EVs on tariff design. To study these effects, we use a game-theoretical model inspired by Schittekatte *et al.* (2018). In the model, the regulator designs network tariffs and different non-cooperative network users react to the way the tariff is designed by possibly installing DERs and adapting their EV charging strategy. We enforce network cost recovery, i.e. the total network cost needs to equal the total network charges collected. We study various technology diffusion levels, tariff structure and network costs structures and evaluated the obtained equilibria with a fairness and efficiency proxy. First, we found that the increase of network charges caused by DERs can be balanced by the diffusion of EVs in the network. Second, we found that through the network cost recovery constraint, electric vehicles diffusion and DERs adoption can be conflicting each other. Finally, we discuss these effects on electric vehicle charging costs and DERs profitability.

Methods and Data

In Figure 1 the modelling framework is shown, the interaction between the low-voltage consumer and the regulator is modelled as a bi-level optimization. In the lower level, four kinds of representative users are modelled. Users may be active or passive and in parallel may own an EV or not. With active is meant that they react to the electricity bill by installing solar PV and/or adapting the EV charging strategy when profitable. Passive consumers are assumed not to react to the way electricity is priced, they either do not have the means to invest or are uninformed. Power consumption of users is modelled with single representative consumption profile and EV use with an hourly basis. Having an EV at home mechanically increases the user's consumption in energy. If she is active, she can in addition incorporate the EV charging and discharging into her optimization process. If she is passive, her EV charges as soon as she goes back home and plugs, which is coincident to her daily peak load. In the upper level, the regulator anticipates the consumer reaction and sets the tariff structure (capacity, fixed, volumetric with/o net-metering) which maximises social welfare while making sure that network cost recovery holds. We solve the game with an iterative process where each level takes the result of the optimization of the other level. We evaluate the results of our model using proxies for efficiency (variation of total system costs) and fairness (variation of passive-no EV user bill). We also study the variation of EV charging costs and investment costs of solar PV and batteries.

Results

We first found that consistently with the literature, DERs adoption can lead to inefficiencies and fairness issues when the network tariff is not well designed. When applying the volumetric network charges with net-metering, the historical option in place, the network charge in euro/kWh needs to increase as total net consumption from the grid decreases. On the other hand, as electric vehicles are inducing the opposite effect on this tariff structure as consumption increases. Hence, once combined together, electric vehicles tend to balance the effect of active users on tariff. We exhibit the different conditions of this rebalancing mechanism in function of the tariff structure and the proportion of electric vehicles owners and active network users. In particular, as the increase of EVs has a lowering effect on the network charge, this tends to reduce the profitability of DERs and hence their adoption. In addition, we find that EV charging costs are very sensible to the applied tariff structure and whether the EV is owned by an active or a passive consumer. At last, we find that network cost structure, namely whether the network costs are sensible to the change in total peak demand or whether most network costs are sunk, has a limited impact on our results.

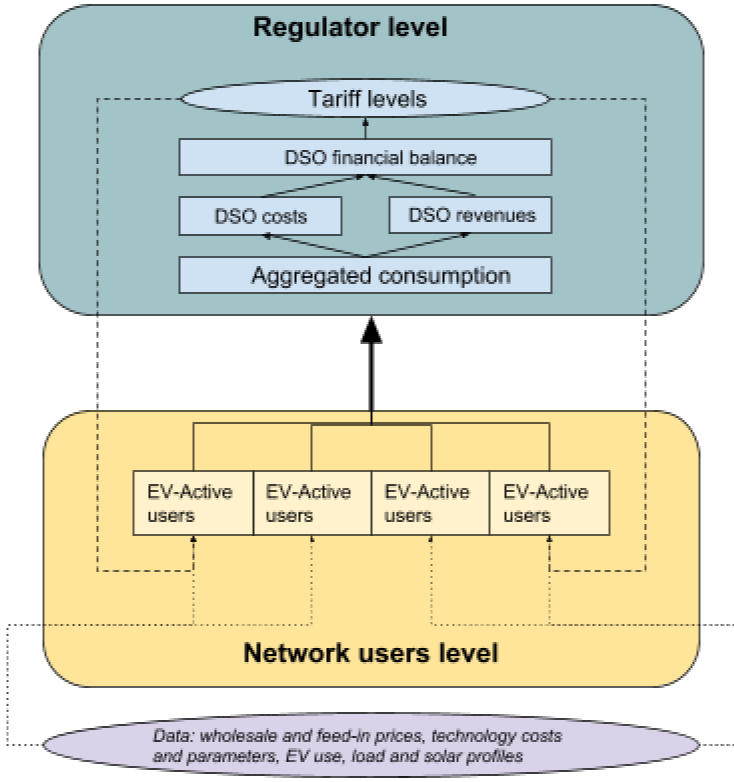

Fig. 1: Model structure

Conclusions

Our study on network tariff design with DERs inclusion enlightened two effects that contradicts general trends of the existing literature. First, contradicting the literature on synergies between electric vehicles and DERS, we found that through the network tariff design, EV and DERs may be conflicting. Second, we argue that the issue of the inadequacy of network tariffs that jeopardize DSO's cost recovery become much less dramatic when EVs are accounted. Future work includes two paths.. First, to analyse this effect in a realistic case study with prospected diffusion of prosumers and EVs. Second, an analytical study capturing all the possible interactions between active users and EV owners.

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