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Renewable Transport Challenge: A Comprehensive Policy Assessment Model

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ABSTRACT

With the growth of the transport sector and its emissions, the European Union (EU) has obliged member states to increase the share of renewable energy sources. To understand which policies need to be pursued to achieve the objectives set by the EU, a system dynamics model was developed and applied to the case study of Latvia. The model considers the potential of the production and use of renewable fuels, the impact of policies on the development of renewable energies, and factors influencing population choice of transport mode.

Keywords: c

NONMENCLATURE

Abbreviations	
CO_2	Carbon dioxide
DTReM-LV	Dynamic TRansport emission Model for Latvia
EC	European Commission
EEA	European Energy Agency
EU	European Union
GHG	Greenhouse gas
RED	Renewable Energy Directive

1. INTRODUCTION

In 2017, the European Commission's Renewable Energy Progress Report concluded that transport is the only sector currently below aggregated national trajectories at the EU level [1]. The share of renewable energy is one of the primary indicators to measure progress in reducing fossil fuel emissions. In 2009, the Renewable Energy Directive (2009/28/EC) set the target that 10% of all energy used in transport should be from renewable sources by 2020. The latest EEA data indicated that in 2019 the share of renewables in transport in the EU was 8.4%. EEA also concluded that reaching the 10% goal by 2020 was unlikely at both country and EU levels because several countries were far from meeting the target. The following recast of the Renewable Energy Directive in 2018 (RED II) obliged fuel suppliers to ensure an increased 14% share of renewable energy in the final energy consumption of the transport sector [2]. This year, the Commission announced the "Fit for 55" package to provide a legislative framework for achieving the 55% greenhouse gas (GHG) emission reduction target by 3020 [3]. Among other proposals, the package also proposes new amendments to the Renewable Energy Directive.

The European Green Deal sets a very ambitious target of reducing GHG emissions from transport by 90% by 2050 compared to 1990 levels [4]. This envisages the development of alternative renewable transport fuels, including advanced biofuels, renewable liquid and gaseous transport fuels of non-biological origin, and renewable electricity in the transport sector.

This paper describes a newly developed modeling tool for comprehensive planning and continuous impact assessment of energy and climate policies in the transport sector. The model was approbated to the case study of Latvia.

2. MATERIALS AND METHODS

The structure of the proposed modeling tool is shown in Figure 1. The model is made in the Stella Architect software based on a previously developed DTReM-LV model (Dynamic TRansport emission Model for Latvia). The DTReM-LV model projects carbon dioxide (CO_2) emission trends in the Latvian transport sector by 2030 and evaluates the emission-saving potential of a broad set of policy measures [5]. Several substantial structural improvements were made to the initial model, including

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cross-sectoral interdependences with energy, agriculture & forestry and waste management sectors, and the inclusion of socio-economic impact and cost assessment of policies suggested.

The simulation takes place from 2017 to 2030. Modeling results reveal projections of energy demand, CO_2 emissions, and renewable energy share in the transport sector in Latvia and underlying factors influencing the projected development patterns.

The system dynamics modeling approach solves complex problems using the dynamic development research method [7]. This approach allows modelers to understand the behavioral patterns of complex systems (dynamic trends) and make changes in the system, which makes its parameters and structural changes flexible.

2.2 Structure of the model

The model is based on the relationship between the

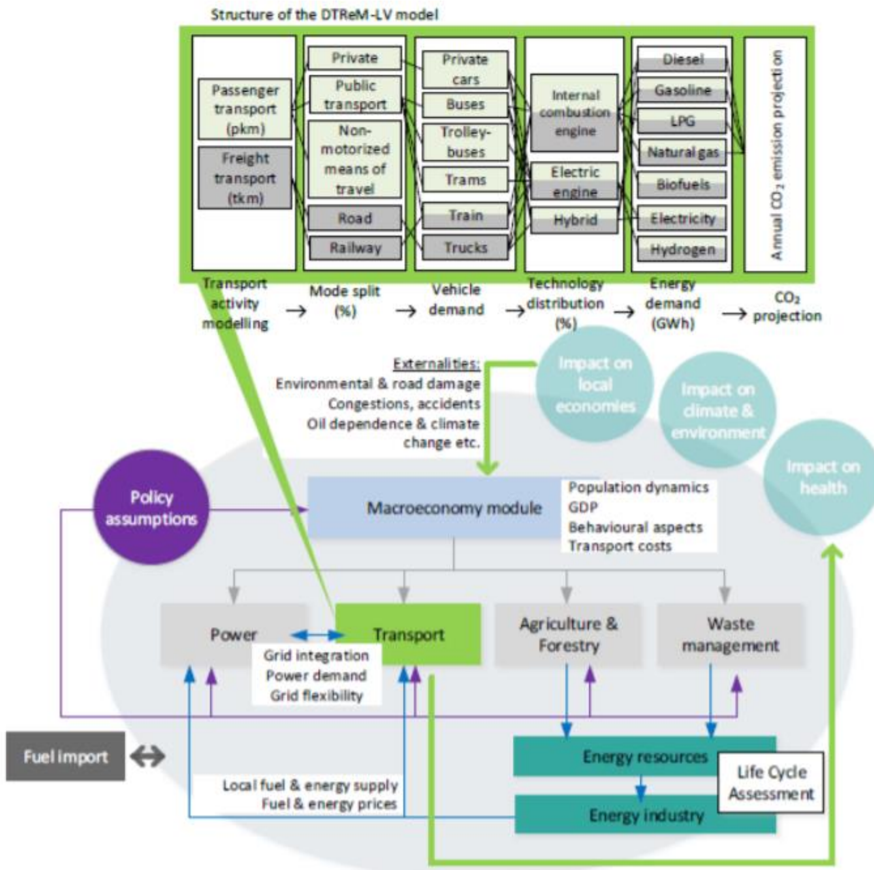

Fig. 1. The structure of the system dynamics model for sustainable transport policy analysis

2.1 System dynamics modeling

The proposed model is based on the system dynamics modeling approach. The analysis of the system structure is based on the concept of two-way causality or feedback. This concept involves linking decisions to information about the system's state or the environment, including the decision-maker himself. The goal is to make decisions based on which actions will change the state of the system. The changes introduced in the system affect future decision-making and thus also future changes. Each closed causal chain forms feedback; many links together form system dynamics models [6].

transport demand in passenger and freight transport, modality of transportation, technology distribution, and technology efficiency (fuel consumption). The model user can change assumptions about parameters such as transport demand, modal split, technology split, technology efficiency, resource prices, etc. The model allows analyzing changes in the CO_2 emissions balance based on assumptions made by the user. For example, what will be the effect of reducing the demand for passenger transport, which will be accompanied by an increase in the number of electric cars, more cycling or public transport, and so on. Based on modeling assumptions, results in terms of CO_2 emissions and renewable energy share are obtained.

2.3 Scenario design & testing

Three main CO_2 reduction directions are considered in scenario runs following the "Avoid-Shift-Improve" sustainable mobility concept. Firstly, the "Avoid" strategies aim to improve the system's efficiency by reducing the need to travel. Secondly, the "Shift" strategies aim to enhance trip efficiency by shifting from private cars to more environmentally friendly modes of transport. Finally, the "Improve" strategies seek to improve vehicle efficiency by introducing alternative fuels and improving energy efficiency.

3. RESULTS

An innovative system-dynamics-based integrated modeling tool for comprehensive planning and continuous impact assessment of energy and climate policies in the transport sector in Latvia was designed, developed, and validated. Based on model results, improved policy formulation and evaluation analysis for elaborating coherent and comprehensive transport policies, emphasizing strategies for increasing renewable energy share. The pathways consider the co-existence of different technologies (both existing and new) and the need for national support mechanisms to accelerate the transition. The baseline scenario and policy scenarios with specific goals and achievable results were defined involving the following policy instruments:

- P1: Alternative fuel charging policy;
- P2: Alternative fuel vehicle purchase policy;
- P3: Alternative fuel information campaign policy;
- P4: Rail electrification policy;
- P5: Mode shift policy (passengers);
- P6: Mode shift policy (freight);
- P7: Biogas production and upgrading support policy;
- P8: Remote work & services policy;
- P9: Old vehicle scrappage scheme policy, and;
- P10: Fossil fuels tax policy.

First, the baseline scenario was simulated, and later the existing, expected, and new policies were designed across sectors. The policies were simulated in isolation at first and then in combination. This allows us to estimate the specific impact of each and whether current policies are creating any synergies or bottlenecks (side effects). Based on the modeling results, policy recommendations were developed to address environmental, social, and economic challenges the transport sector faces.

Modeling results showing CO_2 emission saving potential under each of the three emission reduction strategies are presented in Table 1. Policy measures to reduce the need to travel result in a 5-8% reduction in emissions compared to the baseline scenario. Policy measures aimed at shifting to more environmentally friendly modes of transport result in a 2-5% reduction in emissions compared to the baseline scenario. Policy measures aimed at improving the energy efficiency of transport lead to emission reductions of up to 8% compared to the baseline scenario. None of the analyzed policies implemented separately gives considerable effect on emission savings. However, when implemented in a combination, policy measures show the potential to reduce CO_2 emissions by around 30% in 2030.

Table 1. Modeling results: annual CO_2 saving potential compared to the baseline

Approach	**CO_2 savings, % compared to the baseline scenario**	**Policy measures**
Reduce travel	5-8%	P8, P10
Mode shift	Increased public transport share: < 5% Increased cycling share: < 2% Mode shift in freight transport: 2-4%	P5, P6
Improve efficiency	Increased alternative fuel share up to 10% of stock: 5-8% Improved energy efficiency: 6%	P1, P2, P3, P4, P7, P9

4. DISCUSSION

Well known optimization models applied in the transport sector include the TIMES model (e.g., for China and US transport sectors [8] and Denmark [9]), the MARKAL model (e.g., for India [10]), the LEAP model (e.g., for Korea [11]). These optimization models provide policymakers with insights on policy impacts and offer projections of significant variables and, in some cases, can provide insights on the interactions between macro-economic development and energy management, but rarely vice-versa. The conventional models are also poor at representing consumer behavior [9], which is critical when addressing transport challenges. E.g., the modal shift between transport modes in traditional energy-economy models is evaluated under "what if" scenarios by assessing the effect of exogenously assumed levels of modal shift. But from the policymaker's point of view, it is most interesting to understand how the mode shift can be achieved. The primary strength of the system dynamics modeling approach is its unique "systems" perspective and capability to address the fundamental structural causes of problems arising in complex dynamic socio-economic systems. This advantage is especially beneficial in the transport sector, represented by complex linkages between system elements, feedbacks, nonlinearities, and time delays. The "white box" modeling approach makes researching the existing causalities more efficient in the transport system and builds understanding and conference of the dynamic behavior generated by the existing system. Moreover, this approach allows further improvements in the structure of the model and assumptions used, thus ensuring the opportunity for accuracy improvement of the model and its use for transport system analysis from other perspectives or within the context of other country's case studies.

The proposed modeling tool extends the existing scientific knowledge in the field in the following ways: (i) by addressing the causal relationships within the transport system actors and processes that are usually replaced with exogenous assumptions in conventional energy-economy models; (ii) by including a comprehensive package of cross-sectoral policies that include the direct costs of policy implementation and the less obvious costs, net social costs avoided and benefits of policy implementation; (iii) by taking an integrative approach that combines not only technology solutions with regulatory framework conditions to minimize costs and maximize impacts but also the integration of behavioral aspects in techno-economic modeling, and (iv) by extending the traditional scenario modeling approaches with a cost-benefit analysis.

Modeling results are applicable by governmental stakeholders for assessment of both the existing and planned transport and energy policies, including answers to the following questions: Which sectors of the economy and society need interventions of the public powers? What are policy measures available for bringing the desired changes in the socio-economic context? What are the expected effects? What are the budgetary implications of the policy measure? Modeling results can be practically used for evaluation of the efficiency of existing policies against national targets and tracking progress, assessment of the potential pathways for changes in the transport sector, to foster the achievement of goals, and planning and producing strategy documents such as alternative transport energy strategy, low-carbon strategies, updates of Nationally Determined Contributions, etc.

The future development of the model will focus on long-term analysis, extending the modeling period until 2050 and looking for strategies on how to achieve ambitious Green Deal goals in life.

5. CONCLUSIONS

This paper describes a newly developed mathematical energy-economy simulation tool for national-level policy formulation in the transport sector, emphasizing renewable energy potential. The model was used to research the case study of Latvia. The research aims to find optimal solutions for achieving climate and energy policy goals by 2030 and beyond.

The results indicate that traditional policies can deliver CO_2 emission reductions up to 30% by 2030 compared to the baseline scenario if implemented collectively. However, this is not enough to be on track to meeting the ambitious goals of the European Green Deal. Further research is needed on the integration of new policy settings giving more significant effect and the topic of coupling of the transport and energy sectors through power-to-gas and vehicle-to-grid technologies, thus marking the role of transport not only as a provider of mobility but also by providing an energy storage and transformation function leading to improved overall energy use efficiency.

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