Who gains and who loses in the shift to electric vehicles: impact assessment through multi-criteria multi-stakeholder analysis

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Abstract

Studying the case of the subsidy for electric vehicles in Great Britain ("plug-in car grant"), this research suggests an integrated impact assessment approach by coupling policy issue system modeling with stakeholder preference elicitation.
In particular, we utilize fuzzy cognitive mapping to model the policy issue as a dynamic and complex system. We further simulate the subsidy policy in the model to estimate the changes in select policy aspects. The simulation outcomes are assessed through perspectives of stakeholder groups. For the latter task, nine stakeholder groups were identified and profiled by conducting content analysis and applying the novel CAR method.

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Keywords: stakeholder analysis; impact assessment; electric vehicles; public policy analysis; multi-criteria assessment

1. Introduction

Assessing policy impacts is a prerequisite for any public policy and associated interventions. Impact assessment, in general, analyses attainment of intended goals along with other likely affects and consequences of a policy initiative. Policy impacts, in general, are usually considered to fall into the three categories: economic, social and environmental. These categories result in three corresponding types of traditional impact assessment, with their corresponding methodologies. Obviously, approaches tailored to a particular category cannot analyse intervention's impact comprehensively, e.g., due to ignoring possible interactions between the categories. A systems approach is required in order to analyse the policy issue complexity and provide holistic overview of possible outcomes (1).

Furthermore, while conventional impact assessment focuses on expected effectiveness of interventions in fulfilling a predefined set of goals, the goals might not represent interests of all the important stakeholders. Moreover, stakeholders differently perceive importance of the goals. Ignoring stakeholder preferences in the assessment might result in conflicts between stakeholders, resistance to the change implementation, and ultimately not balanced and comprehensive solution, which risks to undermine initial intentions of the intervention. Thus, policy impact assessment should analyse not only the likely objective outcomes, but also analyse what threats and opportunities those outcomes create for different stakeholders.

One of the domains where different interacting systems create significant complexity for policy makers is transportation. A recent challenge in the domain is a transition from conventional cars to electric cars. Electric cars are automobiles that are propelled by electric motors, using electrical energy stored in rechargeable batteries. While in most countries the market share of electric vehicles (EVs) is insignificant, Norway enjoys over 22% of the share.

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Moreover, Norway has recently announced the complete ban of petrol powered cars by 2025 (2). This example, albeit exceptional, shows feasibility of the complete transition.

The UK government also committed intention and efforts to promote uptake of EVs in the country. The Office for Low Emission Vehicles was introduced as a cross department body, with the budget over £900 million to support the early market for ultra-low emission vehicles. A few particular programmes were introduced to improve the uptake. A widely known programme is the Plug-in Car Grant - the subsidy (upto 5000 GBP) for individuals towards purchase of electric cars. The measure seems effective, as the The Society of Motor Manufacturers and Traders celebrates a 226% sales rise for hybrids and pure EVs in 2015 (3). Yet, it is unclear what costs (of any nature) are to be paid, and how other stakeholders will be affected.

As part of this study we aim to conduct an independent impact assessment of the aforementioned subsidy programme as part of the broader transition to EVs. To this aim this study suggests a practical methodology for a comprehensive multi-stakeholder policy impact assessment.

The remainder of the paper starts with the overview of barriers, facilitators and other details on the transition to electric vehicles. Further, we present the methodology built upon mixed methods to couple system modelling of a policy issue with stakeholder preferences modelling. In the later part, we demonstrate application of the methodology to the case of the subsidy to EVs in the UK as part of a broader transition to EVs. We present preliminary results and demonstrate what kind of analysis the employed approach can enable. Conclusions and future developments conclude the paper.

2. The silver bullet of electric vehicles

Electric mobility is not a novel concept: the first EVs appeared in the 19th century, deemed to prevail over petrol and steam cars. However, the current environmental concerns such as global warming and air pollution have boosted the development of electric mobility. Besides, the environmental benefits, the EVs are expected to change many other spheres of life. The rest of the section provides a literature summary, overviewing motivations and concerns regarding EV market expansion.

2.1. Environmental concerns

As climate change has recently gained much priority on the global political agenda, EVs are promoted as one of the main means to reduce the CO_2 emissions, thus fighting the global warming. Indeed, the decarbonisation of road transport could result in substantial carbon emissions reduction. In the UK a quarter of all CO_2 emissions come from transport; and road vehicles represent 90% of this environmental impact (4). This fact has become a prevailing argument for the transition among policy makers.

Yet, it's worth noting that EVs can only be as green as the electricity used to charge their batteries (5). CO_2 would be still released not only at the point of electricity generation, but at EVs production as well. Thus, although the EV is approximately five times more efficient than the average fossil fuel-powered car (6), the engines of modern petrol-powered cars can be still more efficient than some fossil fuel power plants (7). Hence, in order to estimate the impact of EVs on reducing CO_2 emissions, the electricity generation technologies along with the energy mix must be taken into account.

Besides lesser GHG emissions, electrification of transport could significantly decrease air pollution thanks to almost zero tailpipe emissions. Finally, EVs should also decrease noise pollution in cities.

While generally the transition to EVs should positively impact environment, there are a few negative concerns. One is the risk that the used EVs' batteries, instead being properly recycled or reused as stationary energy storage, will become hazardous waste.

Another threat concerns biodiversity. As the current production of EVs and their batteries consumes mined resources, including rare earth metals.

2.2. Political concerns

The major political motivation for shifting to the EVs is explicitly presented in the UK strategy for ultra low emission vehicles (8). The UK government strives to reduce dependence on foreign fossil fuel import, particularly oil, instead producing local renewable energy. Therefore, EVs are to become key demand drivers for the renewable energy. This motivation is also quite strong in discussions in Europe (and the US), pointing to the worldwide dependence on petrol for transportation as contributing to economic and geopolitical problems (9). Thus, electrification of transport is expected to drive stronger energy security.

Similarly, renewable energy producers and EVs makers seek opportunities to break the hegemony of oil companies and conventional car makers. Instead, they ultimately aim to replace it with another system lock-in: renewable energy and electric cars.

2.3. Economical concerns

The UK is a known global leader in research and development in automobile design engineering and manufacturing. Meanwhile, introduction of electric cars is expected to revive the automotive industry and give an additional economic boost through new job creation (10).

However, those referring to the new job creation as argument usually misses inevitable disappearance of the old jobs due to the technological shift. Indeed, as the fossil fuel is replaced by “green” energy, the business of fossil fuel companies is to shrink, resulting in massive laying off. No doubt this create further social threats.

Furthermore, the use of EVs and potential of smart grid should provide additional economic benefits through better energy efficiency. Smart grid can also potentially open up energy market to citizen through vehicle-to-grid system (V2G). With such expectations the UK’s electric vehicle market value is projected to grow from \$0.1 to \$1.3 billion between 2015 and 2020 (11). Additionally, V2G system should strengthen energy security by distributing and saving energy among many vehicles.

2.4. Social concerns

Mostly EVs should have significant impact on citizens’ health thanks to less air pollutants, as well as, decreased noise pollution.

Currently, EVs are used mostly by particular social groups: environmentalists, early adopters/technological enthusiasts, people with above average income, young, urban citizens (12-14).

Finally, the prioritisation of EVs has its implications for research in related fields. More research institutions and individual researchers can enjoy increased public interest and knowledge in the field along with extra funding opportunities in the topic.

To conclude, the simple idea of transport electrification is quite complex in implementation and potential effects, some of which are not necessarily positive.

3. Methodology and materials

3.1. Multi actor multi stakeholder analysis

One of goal for the suggested further methodology is explicit representation of views and preferences of the different stakeholders, inter alia, by allowing an individual value tree for each stakeholder group. The organisation and overall idea of the presented approach are similar to the ones underlying the Multi Actor Multi Criteria Analysis (MAMCA) (see 15). MAMCA suggests several steps from problem structuring and modelling, through stakeholder analysis and engagement, to presenting and analysing results. It has proved its usefulness in many transport related problems (15-18); yet, it’s general to apply to any complex policy issue. On the other hand, because of its generality it lacks specific methods to support each proposed steps.

Furthermore, technically the MAMCA is not an impact assessment but a decision analysis framework. Nevertheless, it can be easily adapted for policy impact assessment instead, thanks to the high similarity of the exercises. Indeed, comprehensive ex-ante impact assessment, as complex decisions, requires evaluation of complex situations with multiple aspects (criteria) along with conflicting preferences of multiple stakeholders. As instance, the MCDA has been similarly adopted for ex-ante impact assessment of development projects in (19). Mendoza et al (19) rightfully point out that “the concept of a value tree is quite intuitive and inherent to any valuation exercise, not just in decision analysis but also in impact assessment because of its emphasis on objectives, values and perspectives”.

3.2. The two task groups in impact assessment

The multi-criteria and multi-stakeholder nature of the policy impact assessment has naturally defined two key task groups for data collection and further analysis. The first one focuses on structuring the context of the policy issue, identifying relevant attributes and policy goals, i.e., building a comprehensive multi-criteria model, and finally, evaluating performance of a given policy (scenario) against the criteria.

The ultimate aim of the other task group is prior articulation of stakeholder preferences. This requires identification of stakeholders, defining individual value trees and defining criteria weights, i.e. relative importance of the criteria as perceived by a given stakeholder group.

Although the two task groups have different aims, they are heavily intertwined and should be seen as circularly interlinked until all stakeholders and criteria are identified (20). Thus, the mixture of the methods employed for problem structuring, modelling, data collection and processing have been heavily reused for the both task groups.

3.3. Building a policy issue model

3.3.1. Background research with content analysis

The first step of the analysis consisted of background research. The aim of this step is to gain holistic understanding of the issue of the transition to plug-in cars, establish the context, identify immediate stakeholders, and finally to build a system model for the policy issue.

For this aim over 30 recent documents regarding plug-in cars in the UK, as well as, around the world, have been collected. The documents include main official, formal and less formal documents, which describe the status quo situation with the plug-in cars, barriers and opportunities, as well as, related policy proposals with underlying motivation. Examples of the documents include peer-review papers, official governmental policies and strategies, reports and statements produced by a wide range of stakeholders. we prioritised those documents that expressed the official position and documents that are supported by research. For this reason, most of the corpus consists of policy documents, academic studies and reports. This text corpus has been coded using the Atlas.ti software for qualitative content analysis.

3.3.2. System model of a policy issue

One of the outputs of the content analysis is a set of key concepts, reflecting different aspects plug-in cars can play in the society, as well objectives, assumptions and beliefs associated with them. Moreover, certain indication of causalities between the variables has been derived as well. At this stage the model has been demonstrated and discussed with invited experts in energy.

This exercise has resulted in a qualitative system model, which contains 24 concepts and 47 “cause-effect” relations between them. The model has been represented as a fuzzy cognitive map (21) using the MentalModeler tool. The cognitive mapping technique has been used in growing number of cases as a very approachable way to structure and communicate complex issues (see 22-24).

Finally, the intensity of “cause-effect” relations between concepts have been assessed on a [-1;1] scale with support of evidences from the content analysis and/or making reasonable assumptions.

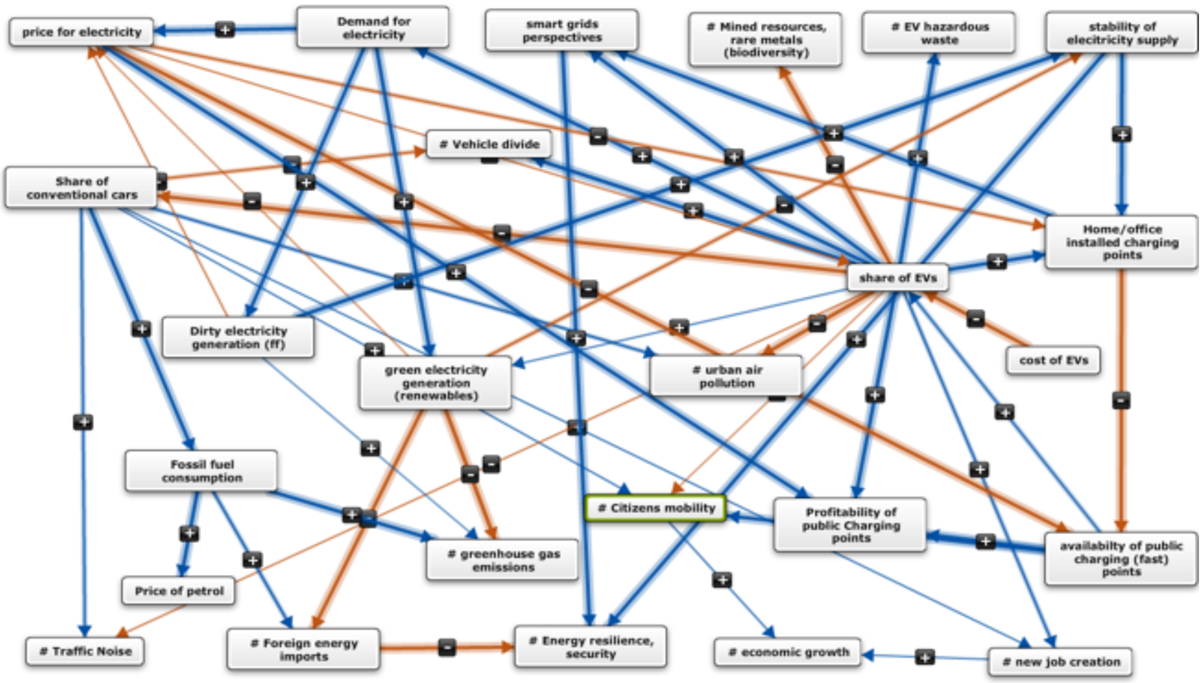

Fig 1. Policy issue model on uptake of electric cars

3.3.3. Simulation

As a second step, the subsidy for purchases of plug-in cars as well as, the "status-quo" (baseline) scenario have been simulated and compared to each other. It's worth noting that the impact analysis by contrasting a proposed policy to the "no policy change" scenario is implied by the EU policy impact assessment guideline (25).

The following procedure is employed. For the baseline scenario calculations start with all concepts having a 'state' value of zero. For the subsidy scenario: it's the same setup, except the initial value of the "Cost of plug-in cars" concept is set to -1. This simulates the reduction of the electric cars price for citizens. Then, the value A_i for each concept at times t+1 is calculated by the following rule:

$$A_i^{t+1} = f(A_i^t + \sum_{i=1, i \neq j} w_{ji} A_j^t) \qquad (1),$$

where A^{t+1} and A^t are the values of concept *i* at times *t+1* and *t* respectively, A_j^t is the value of concept *j* at time *t*, W_{ji} the weight value of the interconnection with direction from concept *j* to concept *i*, and *f* is the "squashing" function used to restrict the concept value into the range of [0,1] (26). These calculations are iterated until the system is stabilised.

It's worth noting, that the absolute values of concepts should be interpreted only in relation to each other, since they only indicate relative magnitude of a change with respect to the "status quo" scenario.

The Figure 2 depicts the relative change of all the concepts in the model.

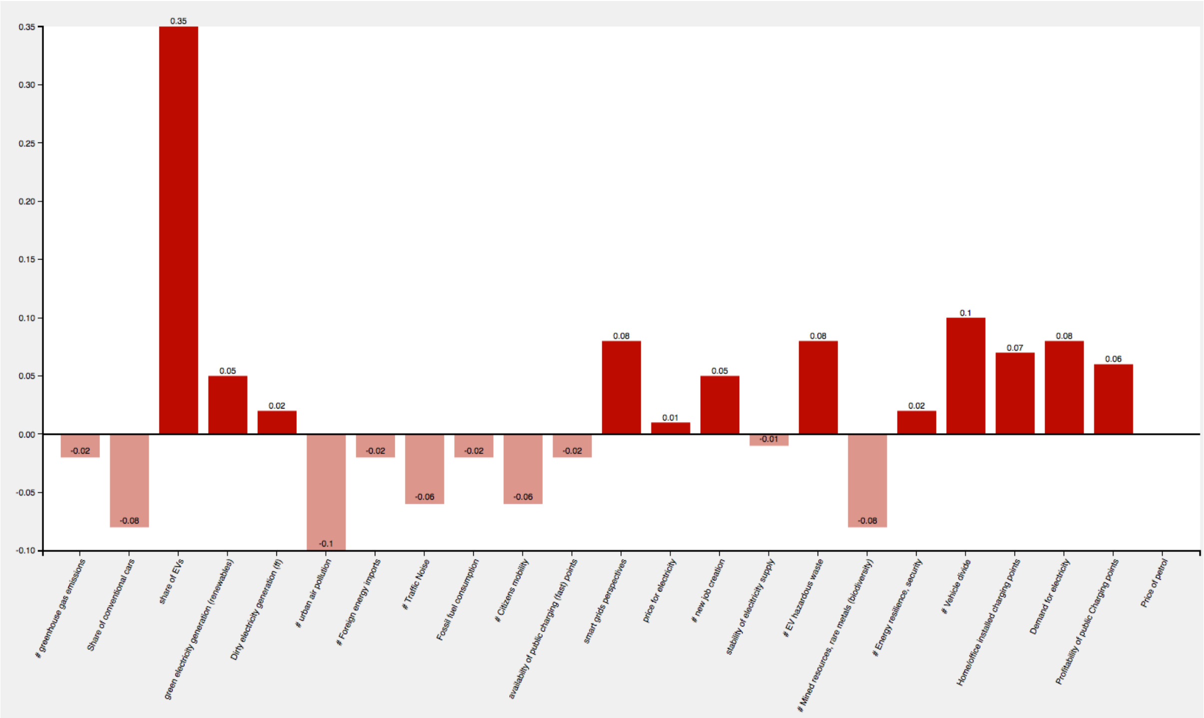

Fig 2. Simulation results for the subsidy policy (Plug-in grant)

3.4. Stakeholder analysis

3.4.1. Stakeholder identification

As the aim of this research is to be as inclusive as possible with respect to considered stakeholders, we utilised several techniques for systematic stakeholder identification.

First of all, the background research has revealed an initial set of stakeholders.

As a second technique, similar to (27), we've associated each of the previously identified concepts in the policy issue model with relevant stakeholder groups. For each concept we attempted to answer a question: "who is immediately involved and affected by a change in the [name of concept]?" As instance, "the share of electric cars" concept is affecting car manufactures (both conventional and electric), owners and operators of public charging infrastructure, certain groups of citizens, etc.

Finally, we applied the value network analysis (see 28) upon identified stakeholders, which explicitly defines interrelations among stakeholders through value exchange flows. The approach reveals external stakeholders, upon which a given stakeholder is dependent in achieving its goals and conducting operations. This approach is similar to the supply chain analysis (18), but it is not limited to actors only involved in trading goods and services but adds actors gaining or losing any form of value, e.g., political support, social status, etc.

Not only does this allow to define interrelations between stakeholders, but it also helps define actors, which can be affected indirectly.

The identified stakeholders have been grouped by homogeneity of their general interests, but also with the aims to better articulate potential opponents, reflect the national (UK) level, and reduce the number of stakeholder groups to a manageable number. The list of defined stakeholder groups includes: government, citizens likely to switch to plug-in cars, citizens unlikely to switch to plug-in cars, electricity suppliers, plug-in car manufacturers, manufacturers of cars with internal combustion engine, renewable energy producers, fossil fuel energy producers, power grid operators, petrol producers.

“Citizens likely to buy plug-in cars” fully or partially encapsulate other stakeholder groups (citizens): such as early adopters, urban citizens, can and want to drive a car, sufficient income to buy an EV, etc. Similarly, “Citizens unlikely to buy plug-in cars” include people risk-averse to new technologies, rural citizens, cannot/ don’t wish to drive a car, insufficient income to buy an EV, etc.

3.5. Preference elicitation

To complete preference elicitation it’s required to define for each stakeholder group: (1) a representative criteria tree (2) the preference direction of each criterion (3) intensity of preference for each criterion.

The criteria tree is a set of criteria deemed relevant for a given stakeholder, the direction of preference refers to whether the higher value of a criterion corresponds to a higher preference value (unidirectional, denoted by +1) or lower (oppositely directed, denoted by -1). The preference intensity is a weight showing relative importance of a criterion in the criteria tree.

For completing this task group we employed either “empirical” or “analytical” strategies, depending on applicability and feasibility with respect to a stakeholder group.

3.5.1. Empirical strategy for data collection

For the empirical strategy we identified appropriate representatives for the stakeholder groups. The representatives are individuals representing a particular organisation, which in turn is a good representative of the whole stakeholder group. For instance, as a representative of the “Government” stakeholder group a policy analysis working for the Office for Low Emission Vehicles of the British government has been contacted. As a representative of renewable energy producers we engaged a top-manager of Ecotricity company.

The representatives are asked to select 1-10 concepts out of 26 concepts used in the issue system model, which are deemed to be relevant and important for the organisation they represent. The representatives were also given opportunity to suggest new criteria, modify and provide their personal interpretations for the suggested ones. These selected concepts are further regarded as criteria. Further, the representatives were asked to define the preference direction for the selected criteria.

Finally, to derive importance weights the representatives were tasked to use the Preference Decision Wizard web-tool [http://preferencedecisionwizard.azurewebsites.net], which is an implementation of the cardinal ranking (CAR) method (29).

The CAR method assumes sliders on a scale. Given a slider with a total Q number of importance scale positions, each criterion i has the position on this importance scale where lower position indicate more importance, such that whenever ci >s(i) cj, s(i) =|p(i)− p(j)|, then the cardinal ranking weights w_i^{CAR} are given by:

$$w_i^{CAR} = \frac{\frac{1}{p(i)} + \frac{Q+1-p(i)}{Q}}{\sum_{j=1}^{N}\left(\frac{1}{p(j)} + \frac{Q+1-p(j)}{Q}\right)} \qquad (2)$$

3.5.2. Analytical strategyfor data collection

The analytical strategy is based on the content analysis and the value network analysis, from which criteria, preference directions and intensity can be derived for given stakeholders. To assist building criteria trees stakeholders were profiled in terms of their needs, goals and means for their achievement.

We further selected subsets of concepts for further use as assessment criteria based on the following requirements: the criteria set should be (1) balanced and diverse, (2) relevant and representative, and (3) preferentially independent for a given stakeholder group. The number of criteria varied from 7 to 9 depending on a stakeholder group.

By judging how increase or decrease in a model concept would impact (positively, negatively, or no impact) stakeholders’ needs, goals and means, the preference directions were inferred for each criteria tree.

Finally, the aforementioned Preference Decision Wizard web-tool was used to map the preferences and calculate the importance weights. A few reasonable assumptions had to be made for criteria ranking, since, while insightful, the value network analysis and content analysis don't explicitly provide evidences of relative importance for all the concepts. The Figure 3 depicts cardinal ranking of criteria by the Government stakeholder group.

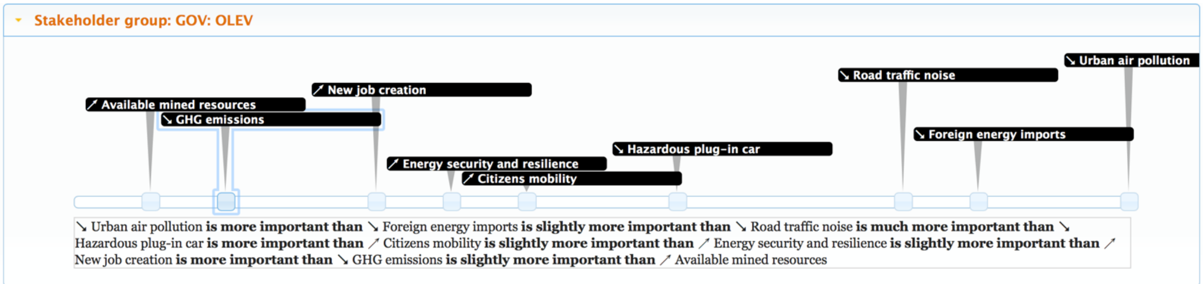

Fig 3. Criteria ranking with the Preference Decision Wizard (the Government stakeholder group)

3.6. Aggregation

In a conventional multi-criteria analysis manner the policy impact on a stakeholder is aggregated as a weighted sum of the concept values and importance weights of the stakeholder group taken the preference direction into account. However, the negative impact (threat) and the positive impact (favour) are aggregated separately. Provided that aggregation is done both for each stakeholder group (Figure 4) and for each concept (Figure 5), this enables balanced view on impact among the stakeholders, as well as, potential impact of each issue concept (criterion).

4. Analysis results and discussion

4.1. Impact on stakeholders

This remainder of the section presents and discuss the aggregated results of the analysis.

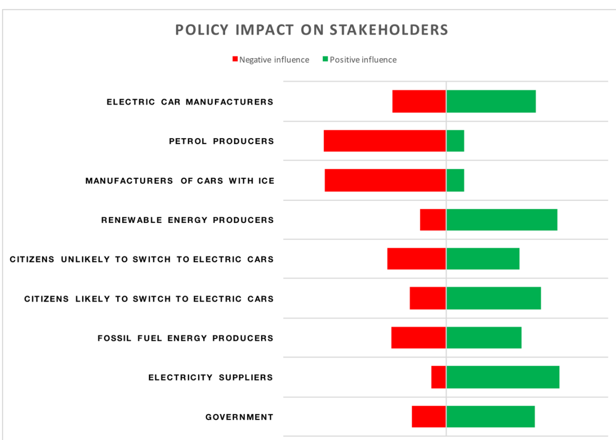

Fig 4. Policy impact on stakeholder groups

The aggregated results (Figure 4) show that, unsurprisingly, the policy significantly threatens such stakeholder groups as Petrol Producers and Manufacturers of Cars with ICE, whereas it clearly favours the Renewable Energy Producers, Electric car manufacturers, Electricity Suppliers and potential buyers of EVs.

Nevertheless, what is worth pointing out is that the policy has mixed impact for all the stakeholders. Even those affected negatively could benefit from the policy episodically. For instance, with the rapid uptake of EVs, the electricity price (especially of "green" energy) should rise. This could favour the petrol producers and manufactures of conventional cars as offering cheaper option.

Moreover, the fossil fuel energy producers (e.g., coal power plants) would benefit from the electricity price increase, particularly in case of insufficient renewable energy supply. Furthermore, if the increased energy demand is fulfilled by the fossil fuel, this would greatly undermine the environment oriented motivation of the transition.

Similarly, the Power grid operators should benefit from the transition in principle, but the rapid adoption of EVs creates operational risks of instability of the grid and misbalance between energy demand and supply.

Finally, there are certain groups, for which the threats and opportunities don't significantly outweigh their counterparts. The unlikely-to-switch citizens are expected to benefit from the better air quality and reduced GHG emissions, while they'll have to pay the expected electricity price increase.

While the transition to EVs in general is seen positively, it also can raise certain socio-cultural concerns and clashes. First, for certain subgroup of the "likely to switch" stakeholder group, the electric car is a symbol of their social status or values. This subgroup includes early adopters, environmentalists, rich people. The expected wider adoption of EVs due to the subsidy might disvalue electric car as the symbol, thus hurting the social status of those people.

A more serious potential issue of is what we call "vehicle divide". The "vehicle divide" can be simply defined as a division of the people using conventional cars and using electric cars. Earlier we identified two counterpart groups: "Likely to switch to EV" and "unlikely to switch to EV". The subsidy clearly benefits mostly the former group, thus, it, albeit indirectly, sets the "unlikely to switch" group into disadvantage. Thus, the penetration of EVs within a single group might reveal and further increase the already existing social and economical gaps between the aforementioned groups. Finally, those who cannot take advantage of the subsidy might rightfully dispute the decision of spending tax money to exclusively support a particular social group, which is already not necessarily in need.

4.2. Impact of policy issue aspects

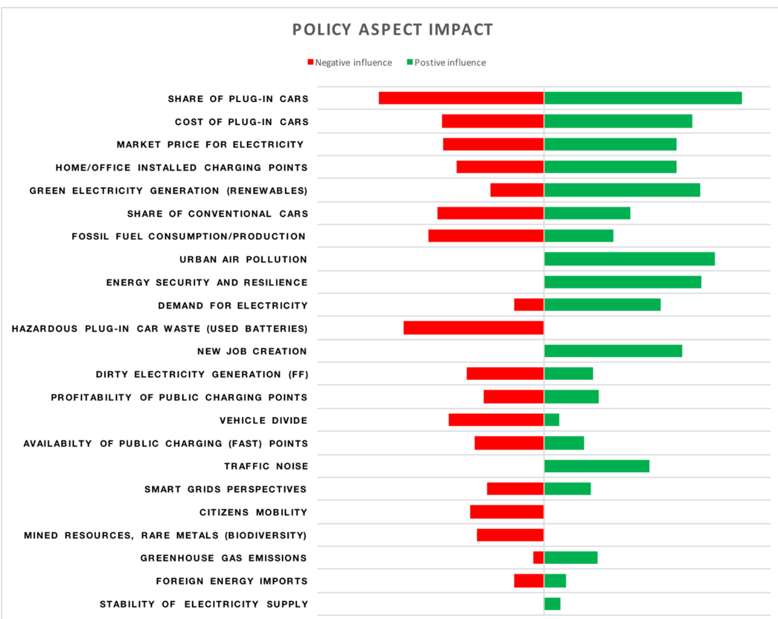

Fig 5. Impact of policy aspects (concepts) on all the stakeholders

The figure 5 depicts potential impact of each analysed policy issue concept on all the stakeholders. Putting this in other way, bars show aggregated utility (negative and positive) of the policy aspects as perceived by the stakeholders included in the analysis. In a nutshell, this analysis should facilitates policy makers to better manage policy implementation and communication strategies by identifying most “sensitive” (both in negative and positive sense) aspects of a policy. Unfortunately, a detailed discussion of the policy aspects analysis is out of scope of this paper.

5. Conclusion

With this aim we suggest an approach for stakeholder analysis in the policy analysis context. The approach is built upon mixed methods coupling system modelling and policy scenarios simulation with elicitation of stakeholder preferences regarding the outcomes of the modelled policy options.

Aggregation of data provides grounds for further prioritisation of stakeholders. Furthermore, it provides a basis for estimation of acceptability/conflict-proneness of a policy, and further guide policy implementation and associated communication efforts.

The approach is demonstrated on the issue of ongoing transition to electric cars in the United Kingdom. In particular, the study assess impact of a state subsidy towards purchase of EVs. The analysis shows that there are clear “gainers” and “losers”, nevertheless, the policy has mixed impact on all the stakeholders. The approach helps to reveal and map potential opponents and proponents along with their “for” and “against” arguments. Moreover, certain non-obvious “complications” of the policy have been revealed and discussed, such as hidden “socio-cultural” costs of the transition.

Although the applied methodology is internally consistent, certain reservations must be made with respect to accuracy of the analysis results of the case. The approach implies making a few assumptions and making interpretations of qualitative data, which inevitably affect the accuracy of the results. The assumptions made in the issue model can be tested against the statistical data with the accompanying model calibration. Yet, other assumptions have to be made when finding proper quantitative proxies to qualitative concepts. As for the preference modelling, a sensitivity analysis is suggested, which allows to estimate validity of the results with certain confidence.

At the same time, the approach is not intended to provide precise estimations, but rather outline potential developments. As the case study shows, even the “quick and dirty” application provides important insights into the complexity of the issue, thanks to the implied problem structuring and modelling, stakeholder profiling, and preference elicitation.

Other future work directions should aim assessment of other proposed policy options, such as, creating green zones, exceptions of tolls, free parking, and others. This should be straightforward, as the policy issue model and list of stakeholders can be greatly reused. Similarly, inclusion of broader number of stakeholder groups into analysis, e.g., NGOs and research institutions, is secured.

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