The Integrated Policy Package Assessment approach: elaborating ex ante knowledge in the field of urban mobility

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Abstract

**Background:** In response to climate change challenges, a main policy emphasis is on transitioning the energy system from high- to low-carbon energy supply. The German energy transition is first and foremost based on political decisions and interventions. These decisions need to be assessed ex ante to ensure a good governance approach to energy policies, for which this paper introduces the Integrated Policy Package Assessment approach (IPPA). IPPA consists of four steps: design, assessment, evaluation and discourse.

**Results:** The results section illustrates the IPPA framework by applying it to urban passenger transport as an example case. First, the design phase was used to elaborate two complementary policy packages each consisting of several policy measures in the transformation pathways of “multi- and inter-modality,” and “alternative drive.” Second, the individual measures of the packages were impact-analysed by a large number of individual impact studies from various disciplines. Synthesizing the individual study results, we developed an impact assessment matrix for impact evaluation. The matrix covers the impact categories: technology development, sector integration, environment, social resonance, and institutional factors. In a further step, the key findings of the impact assessment were reflected and reviewed from the perspectives of various stakeholders and practice experts through a practice–science dialogue on transforming the urban passenger transport system.

**Conclusions:** The discussion and conclusion sections outline the main findings relating to content and process aspects, when applying the IPPA framework to a policy package in urban transport.

**Keywords:** Energy transition, Policy packages, Impact assessment

Background

The transformation of the energy system towards climate compatibility and sustainability—commonly referred to in Germany as ‘the energy turnaround’—is a fundamental process of socio-technical change, which must be actively and purposefully shaped as a “joint effort” [1]. The socio-technical transformation process is characterized by complexity, uncertainty and ambiguity [2–5]. The high degree of complexity results from the systemic intertwining of infrastructure, technology, behaviour, market design and politics. There is great uncertainty with regard to technical development, the decisions of actors and their interactions, or overall future developments both within and outside the energy system. Ambiguity refers to the variety of preferences of citizens, stakeholders, entrepreneurs and decision-makers as to the path to be taken for energy system transformation.

The energy system is widely understood as a highly interconnected socio-technical system with both sector-specific and cross-sectoral system characteristics and rationalities [6–8]. Throughout the supply, distribution...
and use of energy in the electricity, heat and mobility sectors, technical components are closely linked to social and institutional actors and their individual and collective decisions. In such an understanding, technical, institutional, economic and social parameters come together and interact closely. The energy system as it is today or is desired to be in the future is thus a manifestation of this interplay and is characterized by a high degree of complexity [9]. Regarding knowledge of energy supplies, it is a challenge to determine the exact initial configuration (boundary conditions) and the interactions between the influencing factors (interdependencies) intersubjectively [10].

The transport sector is an excellent example of such complexity, uncertainty and ambiguity [11, 12]. The sector is much more complex than other energy sectors. Despite all the political objectives, it has not yet been possible to reduce greenhouse gas emissions from transport in Germany decisively below the 1990 level. On the contrary, emissions are rising continuously—even if a slight decrease can be observed in 2018 [13]. Economic interdependencies in highly specialized value chains with a demand for highly qualified, mobile workers with mobility seen as an expression of freedom, individuality and independence, create tension in discussions on the “mobility transition” [14]. Several objectives are linked to the transformation of mobility systems, covering a much broader range of issues than just climate protection through greenhouse gas reduction [15]. The aim is to improve quality of life by reducing air and noise pollution and by making streets, neighbourhoods and cities more human-oriented than car-focused, but also to save time by relieving the burdens on infrastructure and avoiding traffic jams. At the same time, it should be possible to satisfy the mobility needs of individuals. Further, today’s degree of mobility achieved should be maintained, if not even further increased. This is important, as mobility is equated with individual degrees of freedom which should not be curtailed.

Thus, an integrated approach is required. Our research has addressed the question of how to link sustainability target achievement with transition pathways through the ex ante assessment of policy impact, reflecting pros and cons with decision-makers and stakeholders. The Integrated Policy Package Assessment (IPPA) approach is a suggested way to meet these requirements. This paper elaborates its use to assess ex ante knowledge in the field of urban passenger transport.

The paper is organized as follows: “Methods” section sets out the aim and leading research question, and links the work with a literature review. In “Results” section, we present the main results, outlining the IPPA conceptual framework and the IPPA case study focusing on example of the “alternative drives”. Finally, “Discussion” section discusses the results, summarizes the focal points, and draws some conclusions.

**Methods**

**Leading research question**

A substantial social–technical process such as the energy and mobility transition raises fundamental questions. What are promising pathways towards the transition? Which policy interventions and packages are suitable and functionally equivalent? How can the effects and side-effects of interventions in complex policy areas be assessed? What consequences are to be expected from policies, for example, for the environment, taxpayers, companies or individual quality of life? And what are stakeholders’ opinions on proposed transition pathways, policies and their corresponding impacts?

The energy transition is first and foremost based on political decisions, since promising transformation paths towards a climate-compatible future can only be realized through political intervention and adequate policy action. In short: no decision—no transition. However, a key question for political decision-makers is which decisions should be taken to reach sustainability goals, considering both the intended and unintended effects against the background of alternative decisions which may reach the same transition target, but show different impact consequences. This is no easy task, since the assessment of future-oriented pathways is based on an array of hypothetical ex ante assumptions and uncertainties in the area of anticipating future knowledge for socio-technical systems.

What is needed to meet these requirements? The leading research question calls for an integrated approach that closely links the design of adequate transition policies and assessment of their impact profiles as ex ante knowledge provision for decision-makers. The IPPA approach is our contribution, and we illustrate it by applying it to an example case. The twofold task as presented in the “Results” section combines conceptual framework development with case study-oriented implementation work. In this paper, we thus present the IPPA approach, which aims to elaborate ex ante knowledge for experts and decision-makers based on inter- and transdisciplinary research methods. As decision-makers are well aware of what positive and/or negative impacts policy measures will yield, the idea is to provide ex ante knowledge of future impacts on a multidimensional scope with regard to specific policies or policy packages. The overarching objective is to elaborate a framework that integrates heterogeneous research from different disciplines, synthesizes the results in a coherent evaluation.
matrix, which reflects the expectations and assessments of practitioners and stakeholders.1

Literature review and methods

The IPPA approach as conceptualized and illustrated in this paper draws on several research topics in the field of social science-based sustainability research, technology assessment, and system analysis. The conceptual steps of IPPA comprise the four phases of design, assessment, evaluation, and discourse. Design means combining several policy measures and interventions into a coherent policy package [20–23]. Analysis means an interdisciplinary impact assessment in which the various effects of policy packages are assessed ex ante from different disciplinary perspectives [24, 25]. Evaluation means a synthesis of assessment outputs [26, 27]. Finally, discourse comprises a dialogue-based exchange and review by practitioners and stakeholders [28–30]. To sum up, the methodological process specified the overarching objective of integrating and synthesizing heterogeneous impact assessment of policy measures, including the reflections of practice actors and stakeholders as joint application-oriented research. It thus draws on the areas of literature concerning policy packages, impact assessment, and research involving societal actors.

Research into policy packages relates to research regarding policymaking. Standard practice in policymaking is often called “policy patching” [31–33]. Thus, empirical research on the design and content of national and/or international energy and climate policies often shows an ad hoc policy patching pattern. This pattern implies uncontrolled growth of local, regional, and federal state policies and interventions that are rarely consistent with one other [34, 35]. The policy package approach tries to tackle this problem “by considering the interaction of the instruments in a bundle” [36], considering one or more core policy measure(s) in combination with ancillary measures. The ancillary measures need to have one of three rationales. They should either increase the effectiveness of the primary measure, strengthen the acceptance of the primary measure, or facilitate political support for the primary measure [37–39]. The result is a policy package that is, ideally, as effective, efficient, and accepted as possible in order to cope with a given problem [40]. The package mitigates possible unintended effects, increases legitimacy and acceptance of the measures, and/or facilitates their implementation [41]. The approach is usually applied to the design of theory-based policy packages in scientific and teaching environments outside the real-world policy arena [42]. Within this paper, we combined the policy package approach with sustainable pathway identification and policy impact assessment and evaluation.

Sustainability has become the keyword for future orientation to safeguarding societies worldwide in harmony with one another and the biosphere [43]. It is first and foremost a social construct that seeks to improve the quality of life for the world’s peoples [44]. A key issue of sustainability is to integrate the three dimensions of economic, environmental and social (including socio-political) wellbeing targets. Sustainability research serves these efforts in many ways across the three dimensions. Among others, sustainability research documents the status quo, extrapolates and forecasts future developments, develops coherent sustainability transformation pathways, provides problem-solving metrics, indicators and tool assessments, addresses ethics, conflicting goals and deliberation processes, and helps to develop branch and sector-oriented sustainability specifications [45–50]. A special focus within sustainability research is on integrated impact assessment and evaluation, and sustainability target orientation. There is, for instance, a vast body of literature on sustainability impact assessment for the field energy transition and/or energy technologies [51–54]. Within the IPPA framework, we tackle several relevant issues of sustainability research, namely the field of sustainable pathway identification and interdisciplinary ex ante impact assessment. The concept of policy packaging should not focus only on the expected direct impact of the suggested measures, but has to foresee unexpected side-effects and unintended interrelationships with other sustainability goals. Interdisciplinary impact assessment from a variety of science disciplines therefore provides a multidimensional assessment picture in the areas of economic, environmental, and social dimensions.

The field of Responsible Innovation (RI) and Responsible Research and Innovation (RRI) [55–58] address the question of the responsible design and governance of research and innovation processes. The underlying idea is to steer the research and innovation process towards societally beneficial objectives. Science and research on RI/RRI were initially focused on technologies and processes with great societal transformation potential [59] as well as considerable scientific and ethical uncertainties [60]. A distinctive feature of RRI as understood in large parts of the literature [61, 62] is that steering innovation processes according to societal values and needs is interpreted as a collective responsibility. In this view, there is

1 The research was conducted within the collaborative research project ENavi ("Kopernikus Navigation System for the Energy Transition" 2016–2019) [16–19]. The consortium gathered a wide range of technical, economic and social science expertise, with 59 associated partners and 26 associated experts who contributed their experience to the topics of infrastructure, heating and mobility. The project aim was to develop and implement an inter- and transdisciplinary approach to integrate political interventions and measures, and work across the energy sectors of electricity, heat and mobility.
not only an obligation (for example for technology developers or policymakers) to organize inclusive and participatory processes. There is also an obligation for societal actors to engage in a collective debate that shapes the context for collective decision-making. It is in this regard that IPPA can be described as overlapping with RI/RRI approaches. The overlap is mainly in the dimensions of ‘anticipation’ and ‘inclusion’. The ‘evaluation’ component of the IPPA approach includes the different policy measures (or innovations in terms of new technology, infrastructure, policy, regulation) which compose the policy packages, and their interactions, in an ex ante impact analysis informed by the results of a preceding interdisciplinary analysis. This corresponds with RI/RRI’s dimension of ‘anticipation’ [63]. As participative approaches, we used different methods such as stocktaking workshops, a Group Delphi workshop, and a Practice-Science Dialogue.

Results
The IPPA framework concept
The main intention of the IPPA approach was to develop an assessment procedure that integrated evidence and knowledge on functionally equivalent policy packages which aim to implement sustainable pathways towards climate-friendliness, whilst taking inter- and trans-disciplinary principles into account. As a result, we developed an IPPA framework concept consisting of a four-step phase-model with design, assessment, evaluation and discourse as its constituent elements (cf. Fig. 1).

At the heart of the approach is the design of policy packages that are capable of triggering the two transformation paths of “multi- and inter-modality” and “alternative drive systems”, here within the case study of urban passenger transport. The policy packages were developed using a mixed-method design consisting of a literature review, a participatory Group Delphi workshop, and a practice actors’ feedback workshop. In this paper, we will illustrate IPPA implementation according to the “alternative drive” case. The assessment of the policy packages comprised individual impact studies elaborated by contributions from ENavi project research groups. These were equally important, since each study’s method is characterized by specific strengths and weaknesses, and only their combination leads to robust results. The evaluation integrated and synthesized the individual impact studies into a coherent evaluation matrix. The integration aimed to deliver key insights on progress towards the mobility transition (intended impacts), and unintended side-effects and negative consequences. Finally, in the discourse phase, we applied several participatory methods linking discourse with the other framework phases. The policy package design, for instance, processed a Group Delphi workshop evaluating promising pathways and policy interventions, while the impact profiles of the policy packages were subjected to discussion and review by members of “competence teams” and further practice actors. The competence teams were a structural element of the ENavi project which included individuals from the economic and service sector, civil society, and administration concerned with issues around electricity, heat and/or mobility.

The IPPACase study implementation for urban passenger transport
The design phase: developing the “alternative drive” policy package
The policy package design started with an extensive literature review in order to frame and specify promising transition pathways towards a sustainable urban mobility transition in 2050. As a result, two sustainable, complementary pathways were identified:

- the multi- and inter-modality pathway, and
- the alternative drive pathway.

For each pathway, we developed a pathway target definition and compiled adequate policies for pathway implementation via policy packages. The complementary relation of both pathways envisages first, a modal shift towards sustainable effective and efficient transport systems, and second a substitution towards alternative drives in the remaining vehicles. In this paper, we limit the presentation to the “alternative drive” pathways due to a lack of space. The results of the “multi- and inter-modality pathway” will be published separately. For the “alternative drive” pathway, the target formulation reads as follows:
The transformation path “alternative drives” contributes substantially to a climate-friendly and sustainable transport system in the remaining motorized private transport (MPT) in 2050. With the focus on changes on the supply side due to technology development, the penetration of the vehicle fleet with highly efficient alternative drive technologies supplemented by the provision of a climate-neutral fuel mix is at the center stage. Alternative drive refers to the diffusion of purely battery electric vehicles, hybrid vehicles and fuel cell vehicles as well as further efficiency improvements in conventional drives powered by climate-neutral liquid and gaseous fuels (first- and second-generation biofuels, biomass to liquids, power to liquids, power to gas), which also contributes to a climate-neutral MPT. The technology mix of the vehicle fleet and the fuel consumption in 2050 will differ considerably from the year 2021.

The target formulation has been underpinned by desk research analyzing several features of a future sustainable urban mobility. The background analysis identified cause–impact chains, indicators, scope, and target states of a sustainable urban mobility “vision.” The policy package of alternative drives resulted in two core measures accompanied by four ancillary measurements. Table 1 gives an overview of the measures and details the policies. In the following, we summarize the single measures.

The core measure “CO₂ fleet limit value of 60 g/km by 2030” is a lead instrument from the field of the regulatory toolbox. The CO₂ limit for new cars is considered to have the most far-reaching effect as it addresses the entire new car fleet and almost all manufacturers (with the exception of very small fleets). This measure is a typical technology push measure, as it forces manufacturers to push forward technological developments and offer them on
the market, with a focus on CO₂ emission reduction during the car usage phase.

In contrast, the core measure “introduction of a CO₂ component for fossil fuels” is a clear pull measure from the field of economic instruments, which primarily aims to increase the user costs for the MPT based on conventional propulsion and fossil fuels. By privileging alternative drive systems, the measure is intended to create incentives for users to decide to purchase vehicles with alternative drive systems. This will be directly supported by the accompanying measures “reform of the motor vehicle tax” in favour of climate-friendly, fuel-efficient and light vehicles, and “guidelines on parking fees”.

Both measures are intended to further increase the attractiveness of alternative drive systems with additional economic advantages, and thus to encourage users to buy them. Both core measures are flanked by ancillary measures in the field of infrastructure and communication. By promoting “intelligent charging points and tariff systems”, the aim is to prepare the widespread integration of electric vehicles into the electricity grid so that no new barriers to the diffusion of electric vehicles arise. In addition, a target group-specific “information campaign on electric mobility” aims to fill information gaps and provide neutral information on the entire spectrum of electric mobility. In addition, measures in place, such as the privileged treatment of electric vehicles under the German Electromobility Act (EmoG) or tax advantages for company cars need to be continued.

**The assessment phase: processing interdisciplinary impact studies**

The assessment phase was based on sub-projects carried out within the ENavi. These were partly initiated independently from the IPPA approach. In a screening phase, we identified and evaluated on-going ENavi research via written surveys among the project staff [65]. We identified 19 individual impact studies contributing to the alternative drive policy package assessment. Table 2 gives an overview of the impact study’s main objective, the method used and the scientific discipline assigned to the corresponding policy measures. The impact assessment involved various scientific disciplines (political science, institutional economics, industrial economics, innovation economics, macroeconomics, microeconomics, resource economics and environmental psychology). In addition, law, engineering sciences and simulation sciences with different model approaches were involved. Methodologically, the research included a variety of methods, including desk research, document analysis, legal analysis, expert interviews, surveys, conjoint analyses, and computer models. In Table 2, we indicate the availability of data and results.

Several studies dealt with impact assessment of the CO₂ emission performance standard. Study no. 1 analysed the impact of CO₂ limit values on the development over time of the fleet composition consisting of new vehicle registration and the remaining existing fleet. The work focused on re-assessing the current state of the art as described in [71]. As a result, the passenger car limits of 60 g/km in 2030 and 10 g/km in 2050 ensure both a significant increase in the efficiency of conventional passenger cars and an increasing proportion of electric vehicles. From a macroeconomic perspective, study no. 2 used a general equilibrium model to examine various scenarios, each of which used different policy measures, such as CO₂ performance standard. The results indicate that new car purchases change the most over time in the “standard” scenario. In order to comply with the CO₂ limits, there are both substitution effects between the demand classes and drive types, and budget effects in relation to the absolute level of new vehicle purchases. Further research (no. 3) comparatively analysed several instruments towards impact parameters, i.e. effectiveness, uncertainty (for vehicle suppliers), need for knowledge for different agents, need for commitment, revenue generation, and protection of specific investments. Finally, a value chain upstream analysis has been carried out (no. 4), assessing the risks of supply disruptions associated with vanadium-based redox flow batteries for the German market, using the Holistic Risk Analysis and Modelling (HoRAM) method.

The consequences of a CO₂ price component were analysed by four studies. From a microeconomic perspective, one piece of research (no. 5) used the total cost of ownership approach (TCO) to examine the specific effectiveness of the level of CO₂ pricing proposed in the policy package. A law study no. 6 focussed on legal framework settings, and the potential and constraints for CO₂ pricing implementation in Germany. A macroeconomic simulation study (no. 7) used the energy system model REMod in order to show the total avoidance costs arising in comparison with a business-as-usual scenario. As a target setting, the simulation was based on a total reduction of CO₂ emissions of 55% by 2030 and deduced an adequate level of CO₂ price to meet the reduction goal. In an agent-based model approach, study no. 8 depicted possible changes in mobility behaviour and mobility demand due to the increase in the cost of motorized private transport (MPT) via a CO₂ price component.

The accompanying policy measure reform of the motor vehicle tax was covered by just one study. Research no. 9 dealt with the explicit design of the measurement and concluded that the three measures of CO₂ price component, motor vehicle tax reform, and guidelines on parking...
Space management altogether should lead to reduced motorized private transport patterns.

Intelligent charging points and tariff systems were the focus of four assessment studies. From an institutional economics perspective, analyses were carried out for researching capacity allocation options for integrating electric mobility into the electricity system (no. 10), and for researching various management models for implementing fast-charging electric vehicle infrastructure (no. 11). In addition, law analysis assessed the legal framework and problems for charging infrastructure (no. 12). From a techno-economic optimization approach, using the REMod simulation tool (no. 13), the effectiveness of intelligent charging stations use was analysed, and whether grid-supported charging and discharging of battery electric cars has an impact on their use in the vehicle fleet.

Two studies dealt with guidelines on parking fees. One study analysed various options for public parking space (no. 14), while study no. 15 carried out two

### Table 2  Overview of included impact studies

| No. and study objective* | Method | Discipline |
|--------------------------|--------|------------|
| Core I: “CO₂ emission performance standards of 60 g/km by 2030” |        |            |
| 1. Impact of CO₂ limit values on vehicle fleet composition [n.a.] | Cost calculation | Innovation economics |
| 2. Macroeconomic impact of climate policy instruments (CO₂ price, ETS) within different scenarios [66] | Simulation (general equilibrium) | Energy economics |
| 3. Impact assessment of CO₂ emission standards vs. CO₂ price instrument comparison [n.a.] | Decision theory | Institutional economics |
| 4. Analysis of raw material availability (rare earth) for electro mobility [67] | Simulation (Bayesian algorithm) | Environmental science |
| Core II: “CO₂ price component for fossil fuels” |        |            |
| 5. Impact of user cost increase for conventional vehicles of 2% p.a. on the vehicle market [n.a.] | Total-cost-of-ownership | Innovation economics |
| 6. Law-making and monitoring options for CO₂ price implementation [68] | Legal analysis | Law |
| 7. Impact monitoring for CO₂ prices meeting the CO₂-reduction pathway of 55% by 2030 [n.a.] | Simulation (system optimization model) | Energy economics |
| 8. Impact of policy measures (e.g. CO₂ price) on mobility behaviour and demand [69] | Simulation (agent-based model) | Behavioural economics |
| Ancillary I: “Reform of the motor vehicle tax” |        |            |
| 9. Impact of vehicle CO₂ tax reform on total mobility costs and vehicle fleet distribution [n.a.] | End consumer cost calculation | Innovation economics |
| Ancillary II: “Technology development for intelligent charging & tariff systems” |        |            |
| 10. Analysis of various options for public parking space regulation [n.a.] | Impact assessment | Institutional economics |
| 11. Analysis of various management models for implementing fast-charging electric vehicle infrastructure [n.a.] | | |
| 12. Analysis of legal framework and problems for charging infrastructure [n.a.] | Legal analysis | Law |
| 13. Effectiveness of the use of intelligent charging points and vehicle fleet impact [n.a.] | Simulation (system optimization model) | Energy economics |
| Ancillary III: “Guideline on parking fees” |        |            |
| 14. Analysis of various options for public parking space regulation [n.a.] | Impact assessment | Institutional economics |
| 15. Impact of parking fee increase on mobility behaviour patterns [n.a.] | Representative survey in two cities | Environmental psychology |
| Ancillary IV: “Target group-oriented information campaign on electric mobility” |        |            |
| 16. Impact of information campaigns pro electro mobility on different target groups [70] | Simulation (agent-based model) | Behavioural economics |
| 17. Impact of information campaigns pro electro mobility among commercial customers [n.a.] | Interviews, survey (conjoint analysis) | Environmental psychology |
| 18. Design of information campaign pro electro mobility for private households. [n.a.] | Survey (conjoint analysis) | Environmental psychology |
| 19. Analysis of willingness to switch towards alternative drive cars [n.a.] | Representative survey in two cities | Environmental psychology |

Source: own elaboration

*Indication of publication or non-publication as not available (n.a.) in square brackets. Summary results of non-published material is available from the authors on request.
representative surveys in big cities in order to assess the impact of a parking fee increase on mobility behaviour patterns.

Finally, the measure target group-oriented information campaign on electric mobility was assessed by four contributions. Study no. 16 used an agent-based model from innovation and diffusion research to investigate how a target-oriented information campaign would affect the diffusion of electric vehicles. Environmental psychology contributed two studies analysing the main information deficits that would have to be addressed by an information campaign (no. 17), and dealt with designing an information campaign pro electric mobility for private households (no. 18). Based on data available from the two city surveys, an analysis of the willingness to switch towards alternative drive cars, was carried out (no. 19).

**The evaluation phase: synthesizing multicriteria impact profiles**
The interdisciplinary impact assessment shown above provided a great variety of single results within the complex field of urban passenger transport in socio-technical systems. We developed a three-step approach for the evaluation of the impact assessment. First, we set up evaluation criteria according to different aspects of socio-technical systems and adapted them to the case of urban passenger transport. Second, we identified results from the impact studies assigning them to the criteria. Third, we evaluated qualitatively the single policy package measures according to the evaluation criteria.

Evaluation of impacts needs to rely on multidimensional criteria that cover the heterogeneity of socio-technical systems of humankind. We relied on a set of criteria for the transformation of energy systems [64], which distinguishes five principal categories that address several dimensions of socio-technical systems and are equipped with corresponding criteria towards urban transport systems:

- **Technology development.** This includes criteria such as innovative mobility services, alternative drives for MPT, alternative drives for public transport, and intelligent charging infrastructure.
- **Sector integration and coupling.** This comprises the criteria of development of intelligent charging infrastructures, and coupling of renewable electricity generation with the energy demand in transport.
- **Environmental impact.** This includes traditional emissions (air, water, soil, noise), and greenhouse gases.
- **Social resonance.** This covers issues such as empirically measured willingness-to-accept (technologies, policy measures), and empirically measured consumption and investment behaviour (households, companies).
- **Institutional factors.** This includes legal barriers (contradictions, inefficiencies, etc.), political barriers (e.g. overlapping competencies, mismatches between vertical governance levels, lobbying, time delays, etc.), spatial barriers, and economic barriers.

We then identified relevant results from the individual impact studies according to categories and criteria. The aim was to specify relevant indications for the case study on urban transport across the multidimensional socio-technical systems categories from the individual impact studies. While relevant impact results were identified by hands of a survey among project groups, the assignment to categories and criteria was done by document analysis and bilateral conversations with the research teams. Table 3 gives an overview of the variables identified.

In the field of technology development, electric vehicles should not only be used in MPT, but also for innovative mobility service provision, and for public transport. Increased diffusion of alternative drive vehicles needs to be pushed and incentivized by policy measures. In parallel, development and installation of intelligent charging infrastructure needs to be encouraged in order to avoid energy system instability. In the area of sector integration, there is a need to avoid negative effects of the diffusion of electric vehicles on the electricity system at large. Thus, expansion of renewable energy sources is prerequisite for the extended use of alternative drives. For better coupling between electricity generation and use, storage capacities can be used either with battery electric vehicle storage, or with hydrogen production. In the area of environmental impact, the production and use phases are likewise important. While raw material production for batteries is a crucial issue with considerable environmental impacts and uncertainties, alternative drives in the use phase assure improvements for both traditional emissions into air, water and soil, and reduced greenhouse gases.

Social resonance in the sense of social acceptance and social behaviour are of major importance as an evaluation category. As for alternative drives, there is an increase in the cost of private transport. Thus, willingness to switch may be high, but there is a risk of social imbalance. To compensate, alternatives like public transport must be available and affordable. In addition, there is a lack of neutral information and education about the technical characteristics and possibilities of alternative drives, causing a great deal of scepticism about the new technologies. Finally, in the field of institutional factors, several issues remain. Due to legal issues, not everyone can participate equally in using alternative drive vehicles.
As a political issue, there are windows of opportunity currently open for transitioning the transport system with problem pressure via EU specifications, and society’s climate protection claim (Fridays for Future). However, the current Covid-19 pandemic also favours private car driving in the existing (compulsion engine) vehicle fleet. In addition, there is a lack of coordination

Table 3: Evaluation categories and criteria specified with results from the impact studies. Source: own elaboration based on [64]

| Criteria | Variables |
|----------|-----------|
| Category I: Technology development | |
| Innovative mobility services | • Use of electric vehicles for ride-sharing systems |
| Alternative drives for MPT | • Diffusion of electric vehicles in MPT (private and public) |
| | • Range development |
| | • Cost development |
| Alternative drives for public transport | • Diffusion of electric vehicles in public transport |
| Intelligent charging infrastructure | • Development and establishment of intelligent charging infrastructure to avoid system instability |
| Category II: Sector integration | |
| Intelligent charging infrastructure | • Avoidance of negative effects of the diffusion of electric vehicles on the electricity system through the development of charging possibilities that are beneficial to the system |
| Coupling of renewable electricity generation with the energy demand in transport | • Electrification of the transport sector only serves climate protection if the growing demand for electricity is met by the additional expansion of renewable energy supply |
| | • Electricity can be stored in battery electric vehicles directly at the time of generation, provided they are connected to the grid |
| | • Electricity can be used in electrolysis plants to produce hydrogen at the time of generation. This can be stored and used for refuelling independent of the electricity generation |
| | • Electrification thus serves the purpose of sector integration |
| Category III: Environmental impact | |
| Emissions to air, water, soil | • Production: mining and use of rare earths and critical resources (lithium, cobalt, platinum) may be problematic |
| | • Use phase: avoidance of NOx, reduction of fine dust, avoidance of further air pollutants in direct operation. Shift to electricity generation (if non-renewable energies are used) |
| Greenhouse gases | • Production: mining and use of rare earths and critical resources (lithium, cobalt, platinum) |
| | • Use phase: avoidance of CO2 emissions in direct operation, shift to electricity generation if non-renewable |
| Category IV: Social resonance | |
| Empirically measured willingness-to-accept | • Increase in the cost of private transport: intention to switch may be high, but there is a risk of social imbalance; alternatives (public transport and alternative drives) must be available and usable |
| | • Lack of information: there is a lack of neutral information and education about the technical characteristics and possibilities of alternative drives, which is why there is a great deal of scepticism about the new technologies |
| Empirically measured consumption and investment behaviour | • Purchase decision: depending on the level of information, the level of investment, the running costs, the technical characteristics such as range |
| Category V: Institutional factors | |
| Legal barriers | • Status quo: not everyone can participate equally (e.g. tenants cannot instal a charging infrastructure) |
| | • Lack of procurement guidelines: there are (still) no guidelines for public procurement to give preference to alternative drives |
| Political barriers | • Windows of opportunity: current problem pressure via EU specifications, society’s climate protection claim (Fridays for Future) |
| | • Lack of coordination: activities of the car industry, the energy sector and the state to establish charging infrastructures should be coordinated and more goal-oriented |
| Spatial barriers | • Contextual dependency: use of alternative drives, if necessary depending on the type of space (urban/rural), different incentives and systems of measures may be required |
| Economic barriers | • Investment costs: vehicles with alternative drive systems are sometimes significantly more expensive than conventional vehicles, lack of procurement guidelines |
between activities of the car industry, the energy sector and the state to establish charging infrastructures. Regarding spatial issues, there are contextual dependencies with the use of alternative drives between urban and rural areas. Lastly, economic barriers exist towards investment costs. Vehicles with alternative drive systems are significantly more expensive than conventional vehicles. However, state subsidies for electric car purchase have been considerably extended.

The discourse phase: iterative feedback loops with discursive dialogue

The discourse phase applied several participatory approaches to discuss IPPA development and implementation with internal project staff and external stakeholders along several phases of the cycle. Figure 2 displays the participatory methods used at different stages of the IPPA implementation.

In the design phase, we applied a Group Delphi Workshop. A Group Delphi is a variant developed in the 1990s as a modification of the traditional Delphi method [72–76]. The Group Delphi Workshop discussed and assessed predefined target orientation, sustainable pathways identification and corresponding policy interventions and designed policy packages. It resulted in assessing levels of effectiveness, efficiencies and acceptance among adequate policy interventions, and corresponding trade-offs. In the case of the policy package for the “alternative drive systems” pathway, the expert assessments were very similar: firstly, infrastructure expansion has a major influence on all alternative drives discussed; secondly, there was ambivalence with regard to taxation and quantity limits; and thirdly, the accompanying measures were assessed as being very differentiable. The ambivalence regarding taxation and quantity limits was based on the following arguments. In favour of the CO₂ tax is the fact that both existing users and those who want to purchase a new passenger car are affected. In addition, high effectiveness and low side-effects can be expected. The fact that taxes in the high price segment are a marginal aspect for buyers and accordingly have no steering effect on certain groups of buyers speaks against it. One argument in favour of quantity limits is that they are relatively easy to implement through regulation and sanctions, which manufacturers can use to adjust their internal price structure and ensure that the vehicles are purchased. However, there may be a consistency problem, as the quota must be combined with a corresponding infrastructure.

Focussed on the interdisciplinary impact assessment phase, we used the participative methods of written surveys and stocktaking workshops. The two-step survey approach gathered knowledge on impact studies carried out in the ENavi project and delivered specific details on background, leading research questions and methods used, summary and discussion of major results, and assignment to the corresponding measurements within the policy package. The Stocktaking Workshops introduced and discussed both the IPPA implementation procedure and the synthesis of impact assessments.

In the evaluation phase, we carried out a Practice-Science Dialogue. The policy package “alternative drives” (together with the policy package on “multi- and inter-modality”) was subject to critical examination from various perspectives. At this event, representatives from business, politics and civil society together with project staff discussed the preliminary IPPA results [77]. The workshop event aimed at the following objectives: to present the current research results from the IPPA approach, provide in-depth knowledge on selected individual impact study results, and discuss the overall approach of the IPPA. In presenting both pathway cases, we also stressed complementarity with firstly, encouraging shifts towards more efficient modes of passenger transportation, and secondly substitution towards alternative drives within the remaining fleet of vehicles. The recommendations derived from practitioners and stakeholders are depicted in Table 4. What became clear from the recommendations is that IPPA results were contextualized to a broader picture of mobility transition within a socio-technical system perspective.

Discussion

In this paper, we presented an integrated approach for policy package assessment and illustrated the concept focusing on a case study in the area of urban passenger transport. Since many “grand challenges” are characterized by complexity, uncertainty, and ambiguity within socio-technical systems, integrated inter- and trans-disciplinary approaches seem promising—but they are
much more difficult to apply. The IPPA approach consists of a four-phase framework model with design, assessment, evaluation and discourse policy packages. In the following, we discuss the main findings according to results on the levels of content and process perspective. First, the scope and depth of content results from both the overall IPPA approach, and the individual impact assessment studies is promising. To begin with, the IPPA approach opens up the view of several crucial issues of today’s major challenges in problem-oriented science and policy: firstly, it shows interacting and embedded policies bundled in a package. Second, it considers a heterogeneity of impact perspectives yielding to very different but similarly important results. Thirdly, it provides an overall view on consistently evaluating the different results. And finally, it provides opportunities to discuss the integrated scientific results from real-world perspectives of practice experts from administration/policy, civil society, and business. Thus, the overall IPPA approach may serve as a materialized blueprint approach for analysing policy packaging as policy advice. Second, the process of implementing the IPPA approach remains a major challenge. The conceptual framework of IPPA is an ideal-type approach which is difficult to fulfil in real-world science practice. The continuous need to compromise leaves room for inadequate
results and thus for frustration. Challenges that arise during process implementation include: first, harmonizing timelines and time periods between those responsible in the process across the four process stages. Second, the definition and consideration of comparable policy measurement details within the impact studies are very challenging. These efforts are important in order to ensure all single studies have more-or-less the same research subject and yield comparable results. Finally, a discussion on how the core and ancillary policies relate directly and indirectly to specific impacts and what policy revisions are needed to increase effectiveness, efficiency and acceptance is essential.

Conclusions

One may conclude that the IPPA approach is ambitious with considerable added-value for integrated science, but still has also some shortcomings from a content perspective. The accuracy match between policy package measurement details and consideration of exactly these specifications within the impact studies is difficult to reach. Thus, it was not always clear whether the impact studies adequately relied on the specific measurement configuration when carrying out their impact assessment. The inadequacy may be a result of insufficient consideration when designing the impact studies or a result of difficulties in translating the measurement details into the methods used (survey, simulation, etc.). Another shortcoming is the (non-)comparability or (in)commensurability of the single results. The heterogeneity of single results provision is an added-value for providing insights into real-world impact complexities, but simultaneously these are difficult to put into a coherent synthesis. Which results are more explanatory? Which are less relevant? This is difficult to assess. However, what still remains is the fact that integrated science approaches for policy advice seem to be the road to follow. Even if this road is a challenging one, the added-value of integrated approaches is early consideration of real-world complexities, uncertainties, and ambiguities. It will be worthwhile to spend future effort in trying to achieve solid and feasible concepts and practices.

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Author contributions

The design and implementation of the research behind this article was designed and performed by all authors, i.e. DS, MD, MS, LS, AA. DS was responsible to set up the paper and wrote the main parts of this paper. MD, MS, LS and AA carefully read and commented on the first draft and helped to finalize it. All authors read and approved the final manuscript.

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Availability of data and materials

The authors confirm that the data supporting the findings of this study are available within the article and the data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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