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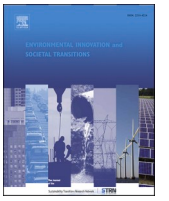

# How media coverage of technologies affects public opinion: Evidence from alternative fuel vehicles in Germany

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ABSTRACT

This paper finds that positive media coverage has a positive effect on individual attitudes towards alternative fuel vehicle (AFV) technologies. The study matches an automated text analysis of six German newspapers from 2018 - 2020 ($n$ = 7,805 articles) with a representative novel survey dataset of citizens in large German cities ($n$ = 1,776). For battery-electric vehicles (BEV), as the most covered technology in the articles, a multiple regression model shows that greater media exposure to predominantly positive articles leads to more positive attitudes. Attitudes towards BEV and hydrogen cars show a low positive correlation, which is in line with the way these technologies are depicted in media, where they are repeatedly presented as competing technologies. To account for the demonstrated effects of widespread media coverage on technology attitudes in this study, transitions scholars and policymakers should pay particular attention to who influences such media messages and to what end.

## 1. Introduction

Sustainability transitions are change processes characterized by negotiations between different actor groups in society. As many transitions revolve around the substitution of key technologies, research on such negotiations has frequently been concerned with actor strategies, public opinion, and discourses about status quo technologies and their alternatives (Isoaho and Karhunmaa, 2019). Discourse studies have demonstrated that the media is a key arena for public negotiation processes and power struggles and reflect the forces in support or hindrance of new technologies (Lee and Hess, 2019; Markard et al., 2021; Rosenbloom et al., 2016). However, this literature has not yet addressed how media discourse on technologies actually impacts on public opinion and how public opinion develops when faced with multiple potential technology alternatives in sustainability transitions. If such media effects are unclear, it remains an open question whether hype cycles in the media, which could be shaped by powerful actors (Konrad, 2006; Melton et al., 2016), have a measurable effect on public technology attitudes. Especially for novel technologies on which the public does not yet have fixed attitudes, this presents an important research gap, since influence over media contents could have a considerable impact on subsequent public perceptions.

Approaches from media studies and studies on technology acceptance can provide the basis for extending discourse studies in transitions, which have previously focused mainly on descriptive and constructivist ex-post analyses and single technologies. First, media and communication studies provide frameworks and research designs for understanding the effects of media on the public. Especially research designs that connect published media content and surveys have so far been underutilized in transition studies.

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Testing the underlying assumption that media content directly affects individuals, therefore brings novelty to the research on technologies in transitions. Second, studies on the effects of alternative options on technology acceptance contribute knowledge on non-technical processes affected by technology interactions (Andersen and Markard 2020). This presents a novel approach as studies on media effects that link coverage to public opinion have so far focused on single technologies (Cacciatore et al., 2012a; Peters et al., 2018), while the few discourse studies on multiple technologies in transitions have not included a measure of media effects (Melton et al., 2016).

Here, the transport sector is used as a case for studying the substitution of technologies and the effects of multiple available alternatives. The key technological change is the move from fossil-fuel powered combustion engines to more sustainable alternatives. In addition to systemic approaches for reducing motorized transport as a whole, this substitution is necessary to tackle the 18% of global $CO_2$ emissions from road transport alone, with the fastest growth of emissions in any sector (International Energy Agency, 2021a, 2021b). Substitution options in road transport are battery-electric or plug-in hybrid vehicles, fuel-cell electric vehicles powered by hydrogen, and alternative fuels such as (bio)gas and e-fuels. In the current transition phase of the transport sector, it is no longer an open question whether these alternative technologies are necessary for reducing emissions but rather how many and which alternative technologies will succeed in what time frame.

*The aim of this paper is therefore to explore how the depiction of alternative fuel vehicle technologies (AFV) in the media affects public opinion on these technologies; and whether attitudes of individuals hinge on portrayed interactions with other technology alternatives.*

This paper contributes to the literature on media studies of sustainable energy technologies and specifically alternative fuel vehicles. It utilizes an effect-centred approach and a linkage design from communication studies, which connects a wide-spanning media analysis with a representative survey dataset. It extends the existing literature by explicitly measuring how the analysed newspaper articles affect the technology attitudes of individual readers. To capture the current situation of multiple AFV technology alternatives, the study adds an examination of the relationship between the alternatives as they are depicted in the media and perceived by individuals. The paper is organised as follows: first, an analytical framework is built based on previous literature. Section 3 then introduces the case and lays out the research design integrating two datasets. Section 4 presents the results, which are subsequently summarized and discussed in the final sections.

## 2. Literature review and theoretical background: media effects and multiple technology alternatives in sustainability transitions

This section situates the work in previous media studies literature on energy technologies in sustainability transitions (Section 2.1) and discusses the merits and theoretical background of an explicit effects-centred study approach (Section 2.2). It then examines how technology alternatives can factor into technology acceptance and how this could be related to joint media depictions (Section 2.3). Finally, takeaways from both research strands are built into an analytical framework (Section 2.4).

### *2.1. Approaches to the role of media in sustainable energy transitions*

Studies on media discourses have become an important part of the literature on sustainability transitions (Rosenbloom et al., 2016), with many studies focusing on energy technologies. There are broadly two research approaches to the role of media, which are mirrored by these studies.

The first approach focuses on public, societal movements, and their representation in media content and seeks to explain changes over time through power struggles (Köhler et al., 2019; Scheufele, 2003). The media is conceptualized as an arena in which actors use discursive strategies to achieve interpretive dominance and power (Scheufele, 2003, p. 42). Amongst other issues, authors have studied discursive strategies on nuclear energy (Teräväinen et al., 2011), energy regions (Späth and Rohracher, 2010), distributed solar energy (Lee and Hess, 2019), coal phase-outs (Markard et al., 2021), fracking (Williams and Sovacool, 2019), and biogas (Markard et al., 2016). The literature on technology hype cycles also follows a content-focused approach. Here, media content is analysed for trends in technology coverage, which can both mirror and reinforce technology expectations of key actors and in the general public (Konrad, 2006; Konrad et al., 2012; Kriechbaum et al., 2021; Melton et al., 2016; van Lente et al., 2013).

A second but related approach measures the effect that media coverage of technologies and discursive struggles can have on its readers. This is the research focus of the study of media effects (Bonfadelli, 2004; de Vreese et al., 2017; Jäckel, 2011; Potter, 2012). In the study of sustainability transitions, we are interested in large-scale processes of change but also in individual-level perceptions and decisions, which can add up to larger changes (Köhler et al., 2019). Attitudes towards novel technologies, which can be influenced by such media effects, are a variable at the individual level that can influence the adoption of innovations and hence larger transition processes.

Only a few studies on energy technologies follow this second, effects-centred approach. Most of this research looks at the potential influence of framing via survey experiments, for examples studies of biofuels (Cacciatore et al., 2012b), offshore wind farms (Walker et al., 2014), smart grids (Broman Toft et al., 2014), CCUS (Vries et al., 2016), and fracking (Bayer and Ovodenko, 2019). By contrast, studies using real media content and its effects on attitudes towards energy technologies are much rarer, and even these have

methodological limitations for understanding public technological preferences. Cacciatore et al. (2012a) look at risk perceptions of biofuels, assessing media usage as a survey variable but without measuring actual media content. Peters et al. (2018) present a multimethod design: they perform a framing experiment in a survey, analyse frames in newspapers, and discuss benefits and risks of smart grids in stakeholder interviews. However, they do not combine these elements and the connection between media content, and individual attitudes are not built into the research design itself. Arlt and Wolling (2016) present a study of media effects on nuclear energy, but since the individual-level behaviour towards nuclear power pertains more to political agreement and voter behaviour, the observed effects cannot be directly transferred to a more consumer-level technology like alternative fuel vehicles.

In addition to the approaches in media studies, the literature strand on attitudes, acceptance, and adoption offers rich insights into the connection between individuals and energy technologies. However, these studies neglect the content of media coverage as an explanatory variable. Indirect effects through variables such as social norm or perceived feasibility are possible but cannot yield any insights into the specific effects of media content. Whether or not media coverage of consumer-level energy technologies can influence the attitudes of its recipients therefore remains an open question.

### 2.2. Theorizing the effect of media on attitudes

In seeking to address this research gap, we need to turn to approaches from the field of media and communication studies (Bonfadelli, 2004; Jäckel, 2019; Maurer, 2017). Capturing changes in attitudes towards a certain topic based on the consumption of media has historically been a contested topic, but is considered possible in current research on media effects (Maurer, 2017). The literature postulates that media can contribute to attitude-building for new issues to which recipients were not exposed before and to reinforcing, rather than transforming, pre-existing attitudes (Bonfadelli, 2004). The reason for this restriction lies in the known cognitive processes related to media consumption. All key approaches in the studies of media effects, revolving around the concepts of agenda-setting, priming, and framing acknowledge the importance of pre-existing beliefs, attitudes, and emotions, and explain media effects through the accessibility and salience of information and the schemata for evaluation available to the recipients (Chernov and McCombs, 2019; Maurer, 2017; Scheufele and Tewksbury, 2007).

Media effects are then a matter of selective exposure, selective perception, selective encoding, and the retrievability of such information from memory (Bonfadelli, 2004). All of these selective processes moderate the effect of media content on attitudes and illustrate why attitude-building and attitude-reinforcing are more likely than large changes in attitudes. Furthermore, media effects have been shown to be weaker for individuals who are highly involved in a topic, for example through their work, and stronger for topics to which individuals exclusively have access through the media, i.e. that are less salient in their everyday life and for which a new attitude can be built based on media (Maurer, 2017).

Noelle-Neumann (1973) approach to studying the media consumption of the general public addresses the recipients' selective behaviour. Aaccording to her analysis: "the effect of a medium is stronger the less it allows the protective effect of selective perception" (summarized by Bonfadelli (2004, p.156) .[1] Based on this approach, strong media effects can be expected if three relevant factors are present: cumulation, ubiquity, and consonance. Cumulation refers to a topic's repeated coverage, ubiquity to its wide spread throughout society, and consonance to the similar treatment of a controversial issue by dominant news outlets (Arlt and Wolling, 2016; Noelle-Neumann, 1973). This study takes up these three criteria for the study of the innovations of alternative fuel vehicles and makes the cumulation, ubiquity, and consonance of media depiction of the technologies a prerequisite for the analysis of media effects.

### 2.3. The effect of alternative options on attitudes

Research on energy technologies and media content shows that multiple technological alternatives frequently compete for media and consequently societal attention (Kriechbaum et al., 2021; Melton et al., 2016). This multi-technology literature treats media content as reflecting expectations about technologies in society and discusses potential reinforcing effects. However, it does not analyse whether the competing depiction of technologies could inform or confuse audiences and potentially alter their attitudes on individual technologies. Sustainability transitions are characterized by large uncertainties, one aspect of which is the simultaneous development of multiple alternatives to replace technologies that jeopardise societal goals. Knowledge about the effect of individuals receiving input about multiple novel technologies in media can therefore be important in understanding the formation of their attitudes and technology adoption, especially if they have not yet come in contact with these technologies in their everyday life.

Micro-processes of technology interaction are already addressed in transition studies. With an approach based in innovation studies, so-called multi-technology interactions between individual technologies are analysed and several interaction loci and interaction modes differentiated: technologies can exist side-by-side, in symbiosis, or compete, with a number of other nuanced interaction modes in between (Andersen and Markard, 2020; Pistorius and Utterback, 1997; Sandén and Hillman, 2011). However, this technology-level micro perspective has so far not included "non-technical processes (e.g. institutional, organizational, and political)"

[1] Translation from German by the author.

(Andersen and Markard, 2020, p. 13), and does not address questions of how the public perceives and acts upon multiple technology alternatives presented in media.

The literature on the influence of multiple technology options on attitudes and acceptance can provide some initial propositions for the current analysis. This literature finds that when multiple alternatives are presented or perceived, the acceptance of a single technology is influenced by these additional options (Ammari et al., 2018; Eikebrokk and Sorebo, 1998; Roddis et al., 2020). In their case study of the acceptance of a large-scale solar farm, Roddis et al. (2020) show that community acceptance depends not only on the characteristics of such solar farms but is relational and "informed by the deployment of other energy technologies and the wider energy policy landscape" (p.241). The studies by Eikebrokk and Sorebo (1998) and Ammari et al. (2018) go a step further by measuring the effect of alternatives on technology acceptance and adoption. Based on an adjusted version of the technology acceptance model (TAM), which includes reference to alternative technologies in the variables 'usefulness' and 'ease of use', Eikebrokk and Sorebo (1998) demonstrate that "technology acceptance in situations where several alternative technologies exist, is affected by a comparison between the alternatives." (p.95). Ammari et al. (2018) find that previously used technologies and alternative technologies used in parallel in a different context can be a so-called 'anchor' influencing the attitudes towards new technologies. They conclude that "it appears that users often make such assessments across alternative technologies not solely based on one particular technology." (p.36). Technology comparisons between the potential alternatives in a given use case have hence been shown to influence technology attitudes and acceptance.

Media effect studies, on the other hand, show that the way in which individuals compare two alternative options, such as political candidates in elections, can be influenced by their comparative depiction in the media (Golan and Wanta, 2001; McCombs et al., 1997). Building on these two strands of literature, I seek to examine whether (1) technology attitudes towards a particular AFV technology are related to attitudes towards alternative AFV technologies and (2) whether any resulting patterns can be traced back to comparisons made in media coverage.

### *2.4. Analytical framework and research questions: media coverage and technology attitudes*

The gaps in research discussed above lead to the following analytical framework for studying media effects of AFV coverage on the attitudes of its recipients, with specific attention to the portrayal of multiple technology alternatives (Fig. 2.4-1).

The framework takes an effects-centred research approach, which focuses on the connection between an individual's media exposure and their attitudes. Attitudes are defined as the "evaluation of an object" (Bohner and Dickel, 2011), with the place of the object taken by AFV technologies. Flaws of aggregate effect analyses in older studies which overestimated media effects due to the ecological fallacy, are addressed in the design, which is constructed as a "single topic individual analysis" (Maurer, 2017). This means that the exposure to the topic of AFV and its effects are measured at the individual respondent level rather than for a population aggregate. Three prerequisites are necessary for assessing a media effect and need to be assessed based on the newspaper coverage. A steady, widespread and similar coverage fulfills the three conditions and allows the transition to the main analysis. Based on the theoretical background and analytical framework, this study then aims to answer the following research questions:

RQ1: To what extent does the media coverage of alternative fuel vehicle (AFV) technologies affect readers' attitudes towards these technologies?
RQ2: How does comparative media coverage of multiple AFV technologies affect the relationship between attitudes towards these technologies?

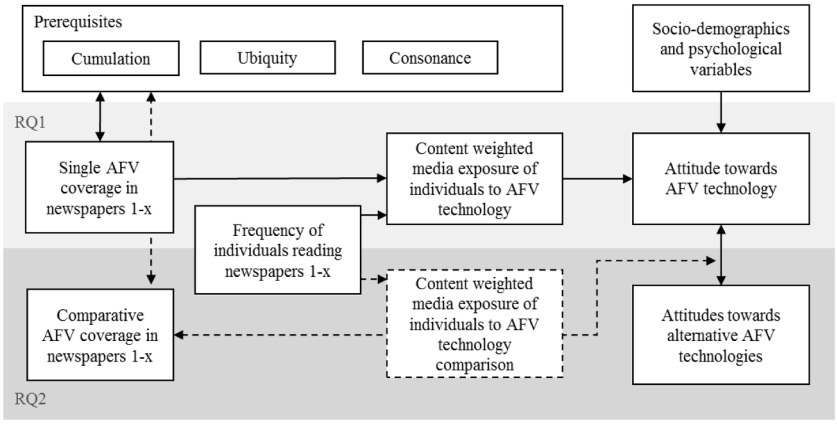


**Fig. 2.4-1.** Analytical framework. *Note.* Dashed lines indicate that prerequisites are not fulfilled for a quantitative assessment of media effects.

**Table 3.1-1**
Overview of alternative fuel vehicle technologies and fuels.

| Technology | Abbreviation |
|---|---|
| Battery-electric vehicle | BEV |
| Plugin-hybrid electric vehicle | PHEV |
| Hydrogen fuel cell electric vehicle | FCEV |
| (Bio)gas vehicle | CNG/LNG |
| Fuels made from renewable energy | E-fuels |
| Electric road systems, catenary trucks | ERS |

## 3. Case and research design

This section introduces the case of alternative fuel vehicles for the study and lays out the research design, which integrates two datasets through a linkage study based on media effects research.

### *3.1. The case of alternative fuel vehicles in Germany*

This research focuses on the case of AFV in Germany, including both cars and trucks. Important parts of the transport sector rely on technologies that need to be replaced to meet $CO_2$ reduction goals, but at the same time are offering several different low- and zero-emission alternatives. This availability of a number of alternatives makes transport a suitable case for studying interactions. The case is also chosen because vehicle technology change is a relevant topic all over the world, so the research results can therefore have a wider importance beyond the German case study.

Germany is selected due to its prominent role as an "automotive country". The country is home to many of the largest global automotive manufacturers who, together with their suppliers, employ around 2% of the German population and almost 8% of all employees in manufacturing (Statistisches Bundesamt, 2019a, 2019b). In 2018, car exports made up 17.5% of German export earnings (Statistisches Bundesamt, 2019c). In addition, in 95% emissions reduction scenarios, the transport sector needs to reach close to zero emissions (Repenning et al., 2015). Not only the economy, but both politics and society are shaped by the automotive industry and make Germany a relevant case for studying technological transitions in the transport sector. If no media coverage effects can be found here, in a country where the industry is so important, they are unlikely to be found anywhere else. This way, the findings for Germany cannot only shed important light on nations with a comparably strong automotive culture and manufacturing but can also show whether it will be worthwhile for the study of media effects in other countries as well.

Table 3.1-1 provides an overview of the AFV technologies included in this study (see Appendix A for more details).

### *3.2. Research design and methods*

The goal of this project is to measure the effect of media coverage on public opinion towards AFV. The research design takes a quantitative multimethod approach that collects and combines two datasets: a media dataset and a survey dataset. The rationale of this combination is based on linkage studies in media research (de Vreese et al., 2017), which address the impact of media consumption on individual's perceptions and opinions towards reality. A state of the art research design is implemented in which the data linkage is done on an individual rather than an aggregate level (Maurer, 2017). This obviates the need for assumptions about reader behaviour by specifically matching the consumed newspaper of each individual with the technology-specific content that was presented in this newspaper during the observed time frame. The project follows a cross-sectional design, utilizing the differences between the individual outlets (Maurer, 2017; de Vreese et al., 2017). The steps in the research process are illustrated in Fig. 3.2-1.

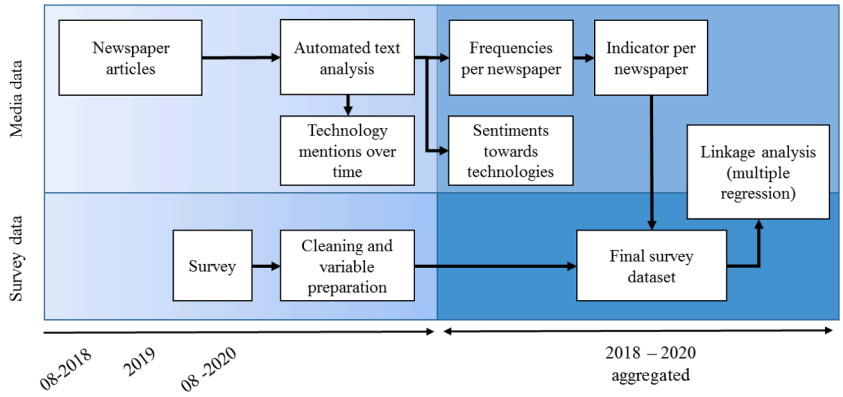


**Fig. 3.2-1.** Multimethod research design combining two datasets.

To achieve the final linkage, five characteristics were matched in both datasets from the start: media category, population, time frame, analysis unit, and the measured topic (see Appendix B for details). As Fig. 3.2-1 shows, the data analysis moves from the media data to the survey data and finally to the joint linkage analysis in the form of a multiple regression analysis. The following sections go through the steps of data collection, data preparation and data analysis first for the media dataset and then for the survey dataset and linkage analysis.

### 3.3. Media dataset: data collection and data analysis

The media dataset consists of articles from six leading national newspapers ("Leitmedien") in Germany (*Süddeutsche Zeitung, Frankfurter Allgemeine Zeitung (FAZ), Handelsblatt, Die Welt, Bild, taz;* both print and online articles) from August 2018 to July 2020. Despite the rise of new media forms such as blogs or social media, these newspapers, which have the largest circulation in the country, remain widely read and can be seen as reflecting public discourse in Germany over this period (Maurer, 2017). The time period covers important events in AFV technology development and policy. In April and August of 2019, the EU set new emission reduction targets for car and truck fleets respectively. 2020 saw renewed subsidies for battery-electric cars as well as the new hydrogen strategy of the German government. The newspaper articles were collected from the database LexisNexis. The search string was created iteratively by scanning media articles for synonyms of all examined AFV technologies and conducting individual pre-searches with the terms. This search yielded 10,074 articles within the chosen time frame.

The large number of newspaper articles ruled out the possibility of hand-coding all material. Instead, an automated text analysis was set up in the open-source software R, mainly using the package quanteda (Benoit et al., 2018). Initial data processing included cleaning, separate variables for dates and page numbers, multi-word detection, stemming, and stop word removal. Analysis was then performed as a dictionary-based co-occurrence analysis based on a bag-of-words logic (Maurer, 2017). After cleaning the data for duplicates and wrongly identified articles, 7805 articles remained.

The final product of the media data preparation was a document-term matrix (DTM) including all AFV technology occurrences reduced to 1/0 (yes/no) per article and technology or combination. A pre-analysis was carried out with the absolute numbers, resulting in a greater weight for technologies that were mentioned multiple times per article. This approach did not, however, lead to significant differences in the coverage ratios between newspapers and was therefore excluded. The DTM could then be aggregated over each month for an overview of the coverage over time, or per newspaper, for the construction of the media content-weighted exposure variable (see 3.4). Variables of average recency and prominence werde added to the aggregated dataset to allow for a robustness analysis, since the literature on media effects finds that content which has been consumed for recently and/or which is presented very prominently in an outlet, for example on the first page of a newspaper, can have a larger effect.

### 3.4. Survey dataset: data collection and data analysis

The survey data was gathered from $n = 1776$ German respondents through an online questionnaire in August and September 2020 and the sample is representative in terms of age, gender, region, and education for German cities with over 100,000 inhabitants (Eurostat, 2020). Respondents were identified through a market research bureau panel. The questionnaire consisted of three parts. First, respondents were asked about socio-demographics. Second, a choice experiment on vehicle sharing services for a different study was presented. This part of the questionnaire did not mention AFV technologies and no particular priming effects are expected from the articulation of personal mobility choices that individuals also make in their everyday lives. The third part included questions on car dependency and technology affinity, knowledge of and previous drive experience with AFV technologies, media consumption patterns, and exchanges on the topic with others. Finally, attitudes towards AFV technologies, trust in societal actors, future expectations towards AFV technologies, and the perceived importance of technology attributes were elicited. A variable of environmental identity was added from the first wave of this survey with the same respondents in September 2019, as this variable can be expected not to change significantly within one year and was not asked again in the second questionnaire.

The dataset contained only complete cases. To utilize the variable of the first wave, however, the two survey datasets were merged and 52 cases removed that were only present in the latter. In total, 1727 full cases remained in the dataset. Gender in the sample was balanced with 50.6% male and 49.4% female respondents. Ages ranged from 18 to 90 ($M = 50.94$, SD = 14.75). Representativeness in terms of education meant that 31.3% of respondents are highly educated (Bachelor's degree or higher). Psychological constructs were measured with pre-tested and published items and checked with confirmatory factor analyses before calculating mean values. In preparation for the multiple regression analysis, four variables were re-coded into dichotomous variables: gender, a related job, education, and previous drive experience with AFV technologies (see Table 3.5-1 for the final variables).

A key variable for the linkage analysis is the daily national newspaper consumption of respondents. The reading frequency for each individual newspaper was asked for with a scale from "daily" to "less than once per month" as is common in media-related questionnaires (Engel and Rühle, 2017). To allow for the weighting of this variable by the actual content of the outlets in the next analysis step, it was transformed into a metric scale between 0 and 1. Finally, based on de Vreese et al. (2017), a variable combining the number of articles on a certain AFV technology per newspaper from the media dataset and the media consumption of individuals was constructed: the *media content weighted* exposure variable. The article numbers per newspaper from the media dataset were manually added to the syntax that calculates the individual exposure to a content feature in a certain media outlet (SPSS). For every individual, their exposure to newspaper k was then multiplied with the amount of articles on a specific AFV technology in this newspaper. The formula for the variable is hence:

**Table 3.5-1**
Variable overview for the multiple regression analysis.

| variable | *scale* | *m* | *sd* |
|---|---|---|---|
| *Dependent variable* | | | |
| Attitude BEV* cars | 1–7 (Likert type) | 4.08 | 1.65 |
| *Independent variables* | | | |
| Media content weighted exposure score BEV* | 0 - 7550 (Metric) | 674.37 | 1227.12 |
| Gender | 1/0 (1 = male) | .51 | .50 |
| Age | 18 - 90 (Metric) | 50.94 | 14.75 |
| (Higher) education | 1/0 | .31 | .46 |
| Related job | 1/0 | .11 | .32 |
| Environmental identity | 1–7 (Likert type) | 5.44 | 1.44 |
| Car importance | 1–6 (Likert type) | 3.96 | 1.51 |
| Technology affinity | 1–6 (Likert type) | 4.03 | 1.10 |
| Knowledge BEV* cars | 1–7 (Likert type) | 4.07 | 1.64 |
| Drive experience BEV* cars | 1/0 | .09 | .29 |

* BEV = main regression model; question was individually asked for BEV, PHEV, FCEV, CNG/LNG, and e-fuels (drive experience excluding e-fuels).

$$\textit{Media content weighted exposure variable}_{ij} = \sum_i \textit{exposure to } [\textit{newspaper } k_i] x \textit{ article number on ZEV technology } [\textit{newspaper } k_i]$$

In addition to the individual exposure data and control variables for the media effects analysis, the survey also provides data for assessing the second research question. To address the two propositions on the effect of alternative technology options derived in Section 2.3, measures of technology attitudes towards all AFV technologies were included.

### 3.5. Linkage analysis: variables for the multiple regression

The study examines how media coverage of different AFV technologies influences readers' attitudes towards the technologies. To assess this effect, the necessary prerequisites for media effects of cumulation, ubiquity, and consonance put forward by Noelle-Neumann (1973) first need to be established. In the analysis, cumulation is operationalised as a constant coverage of the technology from 2018 - 2020. Ubiquity is operationalised as the frequent coverage of the topic in all analysed newspapers. Finally, consonance is operationalized as similar sentiments towards the technology in all analysed newspapers. Coverage frequencies are assessed by clustering the DTM of the media dataset (see Section 3.3) by month and newspaper.

To assess sentiments for determining consonance, two approaches are used. For the articles covering a single AFV technology, a dictionary-based sentiment analysis is performed based on the SentiWS dictionary by Remus et al. (2010) in the updated version 2.0 of October 2018. SentiWS presents one of the most extensive sentiment dictionaries for the German language and includes both standard ratings as positive or negative as well as more detailed weighted scores per term. This way, the share of positive and negative evaluations of the media coverage on the technologies as well as the strength of these evaluations can be assessed. For the articles covering multiple AFV technologies, sentiments towards each technology are coded and compared by hand to determine which technology is portrayed more favourably.[2]

For media coverage meeting the presented prerequisites, the effect of media exposure to AFV on related attitudes is then tested with a multiple regression analysis. Attitudes towards the individual AFV technologies form the dependant variable. The media content weighted exposure variable constitutes the key independent variable of interest. For the main model, the exposure variable contains both articles on cars and trucks since sentiments towards the technologies are expected to overlap and hence influence attitudes towards car technologies as well. To test this assumption, an additional robustness check is performed (see Section 4.1.5). Topic involvement of respondents, as a key moderating influence in media effects studies, is included with a variable on vehicle or energy related jobs. Further impact factors in addition to media effects were identified based on the literature on attitudes and acceptance towards AFV technologies and included as control variables. Table 3.5-1 summarizes all variables that enter the multiple regression. Relevant theoretical evidence for using these specific variables is briefly summarized below.[3] Only the regression model for BEV is kept in the analysis since the results on ubiquity (see Section 4.1.2) showed that coverage of all other technologies is low, at less than 30 articles per technology and year. Given the individual reading scores and likelihood of reading all articles in a given issue, a significant impact of the media content on technologies besides BEV can therefore not be expected.

The general attitude towards each AFV technology was measured with one item each, directly asking for the attitudes towards the respective technologies (Rogers, 1983). Studies on the acceptance and adoption of battery-electric and other alternative fuel vehicles have shown that positive attitudes are related to specific sociodemographic groups such as older males with a high education or income (Hackbarth and Madlener, 2016; Scherrer et al., 2019). Gender, age, and education are therefore included as socio-demographic

[2] Coding is performed for all included articles on a five-point scale (negative, negative to neutral, neutral, neutral to positive, positive). The sample is split equally between two coders and a coding overlap of n = 20 articles is used to discuss and align the coding approach.

[3] The inclusion of multiple items related to media consumption and on all six AFV technologies in the survey necessitated a limitation of technology-specific survey items (attitudes, knowledge, drive experience). Other technology-specific items which have been shown to influence technology attitudes and adoption, such as social norm or Rogers items (ease of use, trialability, compatibility, observability) needed to be excluded.

control variables. Regarding psychological pre-dispositions, studies have shown that the environmental identity of individuals influences their attitudes towards AFV (Whitmarsh and O'Neill, 2010). The importance that individuals place on a car for fulfilling the daily (social) functions in their life, i.e. their perceived car dependency, has been shown to influence how they perceive a new car technology (Steg, 2005). Technology affinity has been shown to have a positive effect on attitudes towards innovations and hence also included. Finally, knowledge about BEV and FCEV has been shown to positively influence attitudes and drive experiences of BEV have been shown to do the same, building the reasoning to include both variables as final independent variables (Preuß and Scherrer, 2021).

## 4. Results

The results section is structured according to the research questions. The first subsection presents an analysis of the coverage over time and per newspaper, including the necessary prerequisites. It is followed by the findings on the effect of AFV technology media coverage on readers' attitudes. Model results focus on the influence of BEV as the most ubiquitous technology in the analysed media and its predominantly positive and thereby consonant coverage. The second subsection then analyses the attitude relationships between alternative technology options and how they relate to the media coverage of multiple technologies.

### *4.1. Effects of media coverage on attitudes towards AFV technologies*

This section presents the results of the media effects analysis. First, the results for three theory-based and one method-based prerequisite of the analysis are presented. Cumulation is assessed through an overview of national newspaper coverage of AFV

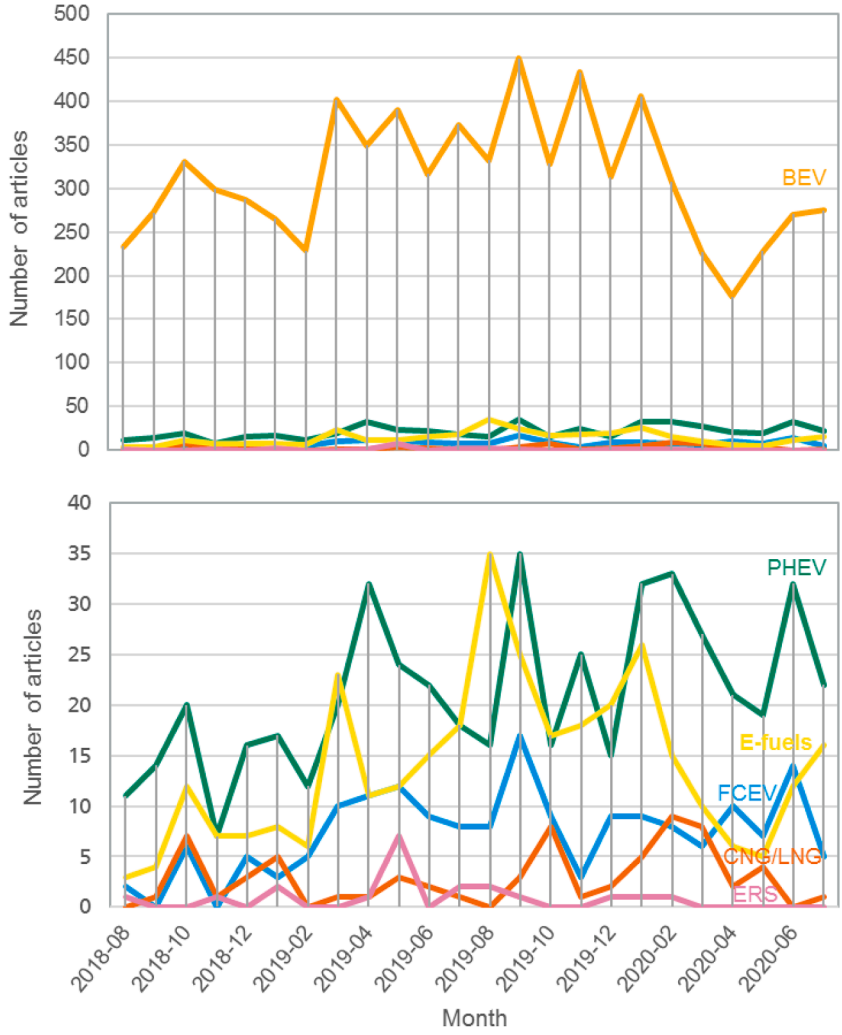


**Fig. 4.1-1.** Frequency of articles on AFV technologies per month in key German newspapers from August 2018 to July 2020. *Note.* Scale difference by magnitude ten between BEV and other AFV technologies. Total per month in figure can exceed monthly article sums since articles with multiple AFV technology mentions count towards each individual score.

technologies in Germany between 2018 and 2020. In addition to an overview of the magnitude of the coverage, observed peaks are also contextualized with associated events. Ubiquity and differences in AFV coverage frequencies are then presented based on an assessment of coverage frequencies between newspapers and technologies. Additionally, consonance in the coverage is assessed through a sentiment analysis The findings of the regression analysis are then presented. For all AFV technologies except ERS, both car and truck applications count towards the summary score. For ERS, counts are limited to trucks as the technology does not extend to cars.

#### *4.1.1. Assessing the prerequisite of cumulation: frequency of AFV technology media coverage over time*

The frequency analysis (see Fig. 4.1-1) shows that the topic of AFV is present in national newspaper coverage with an average of more than 300 articles per month over the period. The frequency of articles with AFV mentions varies over time and differs between the technologies. Battery-electric vehicles (BEV) dominate the coverage, followed by plug-in-hybrid vehicles (PHEV) and e-fuels. BEV are the only AFV technology frequently mentioned as the sole option in articles, while all other options are predominantly introduced in context with alternatives. Fuel-cell electric vehicles (FCEV) and lastly gas vehicles (CNG/LNG) and catenary trucks (ERS) follow but at a much lower number, around one tenth of BEV mentions. For PHEVs and to a lesser extent for FCEVs, an upward trend is visible over the observed time frame. BEV and e-fuels show an upward curve in the middle of the time frame throughout 2019.

The data shows peaks during which the mention of all AFV technologies was higher. These peaks coincide with events in the respective time frames that were identified by examining the newspaper articles of the respective months. The peak in October 2018 can be attributed to the European Parliament voting on new emissions standards for cars and vans in this month. A second peak in August and September of 2019 can be attributed to the economic recession in the country and related lower sales in the automotive industry, coined as the "Autokrise" in the media. The peak in January and February of 2020 can be attributed to three different events: Tesla's plans for a factory in Brandenburg became clear and their stock value increased, BEV subsidies were increased and the manufacturer Daimler faced a crisis. Finally, the peak around June and July 2020 relates to the economic stimulus package related to the COVID-19 pandemic and discussions around car subsidies. One clear separate peak is that of mentions of catenary trucks (ERS) in May 2019. This presents the opening of the first eHighway in Germany on highway A5.

#### *4.1.2. Assessing the prerequisites of ubiquity and varying frequencies: AFV coverage across German newspapers*

The main interest of the study lies in determining the effects of AFV coverage on the public over the assessed time frame. For this assessment, two additional prerequisites must be fulfilled. First, the technology for which a media effect is measured must be covered frequently in all analysed newspapers so that an exposure to the topic by all readers, and therefore a certain ubiquity, can be assumed. Secondly, the levels of coverage need to differ between newspapers to allow for a cross-sectional study of readers with different newspaper preferences and reading frequencies.

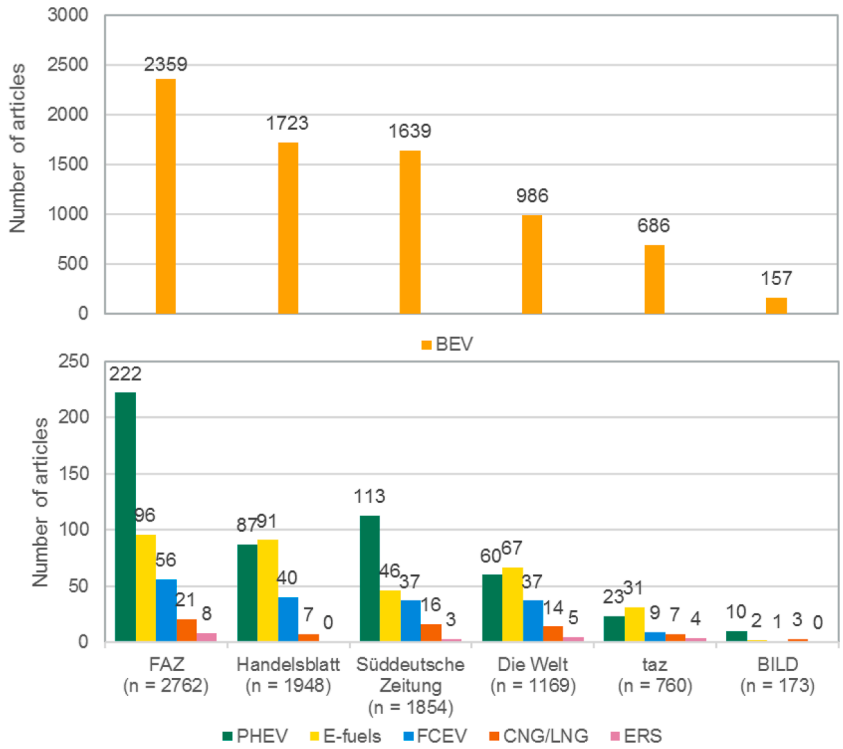


**Fig. 4.1-2.** Number of articles mentioning each AFV per newspaper. *Note*. Scale difference by magnitude ten between BEV and other AFV technologies.

According to the frequency with which they mention AFV technologies (see Fig. 4.1-2), the six analysed newspapers can be categorized into four groups. *FAZ* leads with by far the most articles in total and for each individual AFV technology. *Süddeutsche Zeitung* and *Handelsblatt* take second place with almost twice as many articles on AFVs than *taz* and *Die Welt*, which make up the third group. *Bild* mentions AFVs the least. This ranking is true for all AFVs combined as well as for BEVs and FCEVs separately. For gas vehicles and e-fuels, *Süddeutsche Zeitung* moves below *Die Welt* and *Handelsblatt* respectively, which report more on these technologies. Electric Road Systems or catenary trucks are not mentioned at all in *Handelsblatt* and *Bild* and in less than ten articles per newspaper for the remaining outlets. Adjusting the frequencies of AFV mentions for the volume of the respective newspaper in a robustness check shows that the general patterns do not change. This means that the larger newspapers also reported on AFV more frequently while newspapers with a lower page count reported proportionally less on the topic.

These results show that the prerequisite of ubiquity is only fulfilled by the AFV technology of battery-electric vehicles (BEVs). This technology is covered between around 50 and around 700 times per newspaper per year and therefore ubiquitous in the public discourse. Other distinct AFV technologies like E-fuels, FCEVs, gas vehicles and ERS are only mentioned with a maximum of around 30 articles per year and therefore cannot be assumed to have a consistent effect on the respective readership. In the following, media effects will therefore exclusively be measured for the technology of BEV. The results also show that the newspapers vary in the frequency with which they cover AFV technologies. It can therefore be expected that readers of different newspapers have different amounts of exposure to the topic of AFV technologies. This benefits the analysis as it creates variance in the media content weighted exposure variable beyond the variance caused by different reading frequencies.

#### *4.1.3. Assessing the prerequisite of consonance: sentiments towards AFV*

The sentiment scores for all articles on BEVs were positive overall, with around 69% terms being positive and 31% being negative. Over the analysed time frame, the sentiment scores of all articles focusing on BEVs remained stable (2018 = 70% positive, 2019 = 71% positive, 2020 = 69% positive).

The sentiment scores on BEVs are close together for all analysed newspapers (see Table 4.1-1). The difference in the positive share of terms between the least positive and most positive outlet is 6%. When adjusting for the weight of the positive and negative terms for their respective sentiment strengths, the sentiments for all newspapers stay on the positive side and stay close together, differing by a maximum of 0.02 on a scale from −1 to +1. The ranking stays the same except for the Süddeutsche Zeitung, which moves up to second place, meaning that it uses stronger positive than negative words in relation to BEVs in its articles. Overall, the prerequisite of consonance is therefore fulfilled for the media coverage of BEV and media effects will be interpreted based on the identified predominantly positive sentiments.

Since the regression analysis is based on differences between newspapers, these findings also mean that the exposure variable does not have to be adjusted according to sentiment scores. The minimal sentiment differences between newspapers would not change the exposure variable, which enters the regression analysis as the indicator for newspaper coverage.

#### *4.1.4. The effect of positive BEV media coverage on attitudes*

This section presents the results on the regression analysis, which tests the effect of media coverage of alternative fuel vehicle technologies on the recipients' attitudes towards these technologies. The analysis focuses on BEV as this AFV technology clearly dominated media coverage and a media effect can be reasonably expected. The results shed light on the relationship between respondent's exposure to predominantly positive articles on BEV technologies in the newspaper(s) they read during the examined time frame and their subsequent attitudes towards the technology, taking into account relevant control variables identified from the literature. First, correlations between all variables are presented, with a particular focus on the direction and magnitude of correlations between each independent variable and the dependant variable (see Appendix C). Then, the multiple linear regression model results are presented (see Table 4.1-3).

Scatterplots show that the relationship between the independent variables and the dependant variable is linear. Analysis of collinearity statistics show that there is no multicollinearity in the data, as none of the observed correlations between independent variables was above 0.3, VIF scores were well below 10, and tolerance scores above 0.2 (VIF: max. = 1.464, $M = 1.215$; tolerance: min. = 0.683, $M = 0.831$). The Durbin-Watson statistic showed that the values of the residuals are independent, as the obtained value was close to 2 (Durbin-Watson = 2.069). The plot of standardised residuals versus standardised predicted values showed no obvious signs of funnelling, suggesting the assumption of homoscedasticity has been met. The P-P plot for the model showed that the values of the residuals are normally distributed with only slight deviations from the line in a small number of values. Cook's Distance values were all

**Table 4.1-1**
Sentiment shares for all articles on battery electric vehicles (BEV) per newspaper.

| Newspaper | *Positive* | *Negative* | *Mean sentiment weighted (−1 to +1)* |
|---|---|---|---|
| BILD Bund | 0.66 | 0.34 | 0.002 |
| Die Welt | 0.70 | 0.30 | 0.013 |
| Frankfurter Allgemeine Zeitung (FAZ) | 0.71 | 0.29 | 0.017 |
| Handelsblatt | 0.72 | 0.28 | 0.020 |
| Süddeutsche Zeitung | 0.68 | 0.32 | 0.017 |
| taz, die tageszeitung | 0.68 | 0.32 | 0.005 |

**Table 4.1-3**
Multiple linear regression analysis for media exposure to BEV and attitudes towards BEV.

| | *Unstandardized beta coefficients Attitude towards BEV* | *Standardized beta coefficients* |
|---|---|---|
| (Constant) | 2.978 | |
| Media content weighted exposure score BEV[1] | .00009 | .068* |
| Gender | .121 | .036 |
| Age | −0.011 | −0.097** |
| (Higher) education | −0.086 | −0.025 |
| Related job | .459 | .101** |
| Environmental identity | .247 | .206*** |
| Car dependency | −0.138 | −0.123*** |
| Technology affinity | .035 | .024 |
| Knowledge BEV[1] cars | .080 | .074* |
| Drive experience BEV[1] cars | .588 | .119*** |
| $R^2$ | | 0.154 |
| Adjusted $R^2$ | | 0.145 |
| N | | 1009 |

*Note.* * $p<.05$; ** $p<.01$; *** $p<.001$.
[1] BEV = placeholder in presented main model; question individually asked for BEV/PHEV/FCEV/Gas/e-fuels (drive experience excluding e-fuels).

under 1, suggesting individual cases were not unduly influencing the model.

A significant regression equation is found ($F(11, 997) = 16.547$, $p<.000$), with an overall model fit of 15.4% ($R^2 = 0.154$, adj $R^2$=0.145). Individual predicted attitudes towards BEVs are hence equal to 2.978 + 0.00009 (media exposure) - 0.011 (age) + 0.459 (job) - 0.138 (car dependency) + 0.247 (environmental identity) + 0.08 (knowledge BEV cars) + 0.588 (drive experience BEV cars). The largest explanatory power lies with environmental identity and car dependency, in a positive and negative direction respectively.[4] Individuals' attitudes towards BEVs increases by 0.1 Likert points (1 Likert point) for each increase of 1000 (10,000) in BEV media exposure, representing 1000 (10,000) more potentially perceived articles on BEV in the covered two-year span for a daily newspaper reader (see Appendix C for a more detailed interpretation).

#### *4.1.5. Robustness tests and test for effect of issue salience (cars vs. trucks)*

The model is also calculated with a media content weighted exposure variable adjusted for recency and prominence. This variable gives more weight to articles that appeared more recently and on the first page of a newspaper. This model run leads to no significant difference in comparison to the initial regression model ($F(11, 997) = 16.566$, $p<.000$; $R^2 = 0.155$; coefficients identical up to third decimal place).

Studies have shown that media effects appear in a stronger manner for topics that are predominantly communicated through mass media, i.e. with which people have less direct experiences in their life (Maurer, 2017). A test for whether a differentiation between AFV cars and AFV trucks, with which individuals have less contact, made a difference to the model was therefore also conducted. This involved a differentiation of the variables of media exposure, knowledge, and attitudes for cars and trucks respectively and an omission of drive experience for trucks. Leaving truck articles out of the media exposure variable (around 3% of total BEV articles) did not result in changes to the model. A difference in the expected direction was found for trucks separately: the effect of media exposure was larger for the less salient topic of trucks as represented by the unstandardized beta value (0.003 compared to 0.00009 before). However, the standardized beta value was not quite significant at the 5% level ($p$=.055) and the overall model had less explanatory power than the separate car model ($F(11, 871)$=11.335, $p<.000$; $R^2 = 0.125$).

### *4.2. The role of alternative AFV technology options*

This section presents the results on relationships between respondents' atttitudes towards different AFV technologies and the connection of these relationships to media coverage. First, attitudes towards different AFV car technologies are compared and their interrelations examined. The relationship between BEV and FCEV technologies stands out as the smallest correlation and is set as the focus for the remainder of the analysis. Second, prerequisites for measuring a media effect of articles including both BEV and FCEV technologies are assessed. This includes both analyses of frequency over time and in different newspapers to measure cumulation and ubiquity, as well as a sentiment analysis of all newspaper articles in the sample including both BEV and FCEV technologies. Finally, in the absence of the necessary prerequisites for a quantitative effects analysis, the survey and media findings are qualitatively compared.

#### *4.2.1. Attitude relations between AFV technologies*

Results on AFV technology attitudes show that respondents have neutral to slightly positive attitudes towards these technologies on

[4] Additionally, several models with interaction effects connected to the media exposure variable were run. Only for the interaction term between knowledge about BEV cars and media exposure the coefficient was significant on a 5% level. High knowledge values were connected to a more positive effect of the measured positive media exposure on attitudes but with a small effect strength.

**Table 4.2-1**
Attitudes towards and attitude correlations between different AFV technologies for cars.

| | Attitude FCEV | Attitude BEV | Attitude PHEV | Attitude (bio-)gas | Attitude e-fuels |
|---|---|---|---|---|---|
| Attitude FCEV (Ø 4.91) | 1.00 | .145** | .263** | .404** | .406** |
| Attitude BEV (Ø 4.08) | | 1.00 | .545** | .268** | .412** |
| Attitude PHEV (Ø 4.52) | | | 1.00 | .438** | .439** |
| Attitude (bio-)gas (Ø 4.49) | | | | 1.00 | .653** |
| Attitude e-fuels (Ø 4.37) | | | | | 1.00 |

*Note*. Attitudes ranging from 1 = „very negative“ to 7 = „very positive“.

average (see Table 4.2-1). Battery-electric vehicles receive the lowest score and fuel-cell electric vehicles stand out with the highest average attitude score. Correlations between the attitudes show that overall, a positive attitude towards one AFV technology is connected to a positive attitude towards other AFV alternatives. The strongest correlation can be found for attitudes towards vehicles powered by (bio-)gas and e-fuels, followed by the correlation between attitudes towards BEVs and PHEVs.The weakest correlation is found between attitudes towards BEVs and FCEVs. This means that positive or negative attitudes towards one of these two technologies can only explain changes in attitudes in the same direction in the other technology to a very small extent. This comparatively weak relationship can be of interest for further analysis because it indicates individuals finding differences between the two technologies despite both of them presenting a locally zero-emission technology containing electric components. The connection between BEV and FCEV is hence chosen as the focus for the media effects analysis of technology interactions.

### *4.2.2. Assessing the prerequisites of cumulation and ubiquity: frequency of joint BEV and FCEV technology media coverage over time and between newspapers*

Results in Section 4.1 show that BEVs occupy the largest space in the overall AFV technology discourse in German leading newspapers from 2018 to 2020 while FCEVs rank at the lower end Fig. 4.1-1–4.2-1.

Their joint coverage, as shown in Fig. 4.2-1 never passes above ten articles per month for all covered newspapers. Additionally, the most frequent joint mentions date back to early and late 2019. The prere quisite of cumulation is therefore not met for this combination Fig. 4.2-2.

The pattern across newspapers shows a small and comparatively even distribution of articles containing both BEV and FCEV technologies with the exception of the newspaper taz. However, with a maximum of 35 articles per newspaper over the three year period, the prerequisite of ubiquity for assessing media effects on readers can not be fulfilled.

### *4.2.3. Assessing the prerequisite of consonance: comparative sentiments towards BEV and FCEV*

The sentiment analysis of newspaper articles including both BEVs and FCEVs yields a mixed picture (see Table 4.2-2). 69% of the articles including both technologies also include an evaluation.

The sentiment analysis shows that more than half of the articles including both BEVs and FCEVs take a comparative stance for one over the other technology. 22% favour BEVs while 30% favour FCEVs. An additional 17% evaluate both technologies similarly and in a predominantly positive or neutral way. The articles containing both BEV and FCEV can hence not be considered consonant.

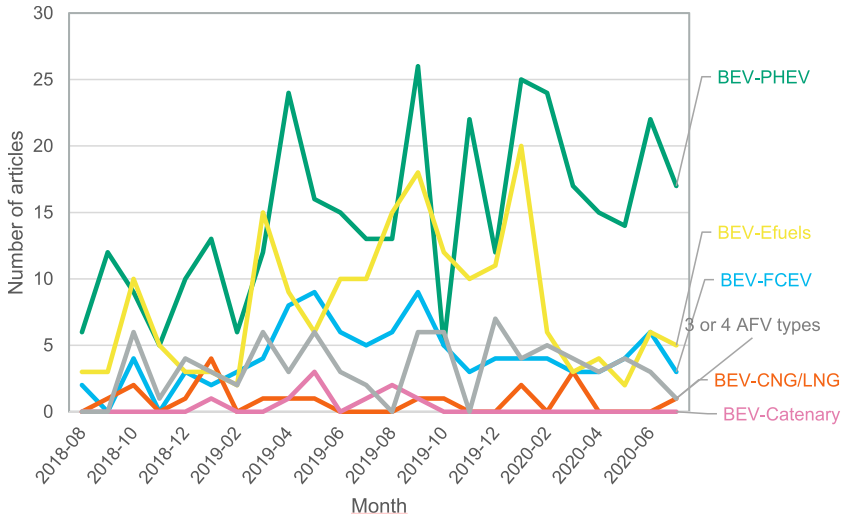


**Fig. 4.2-1.** Frequency of articles per month including two or more AFV technologies in key German newspapers from August 2018 to July 2020.

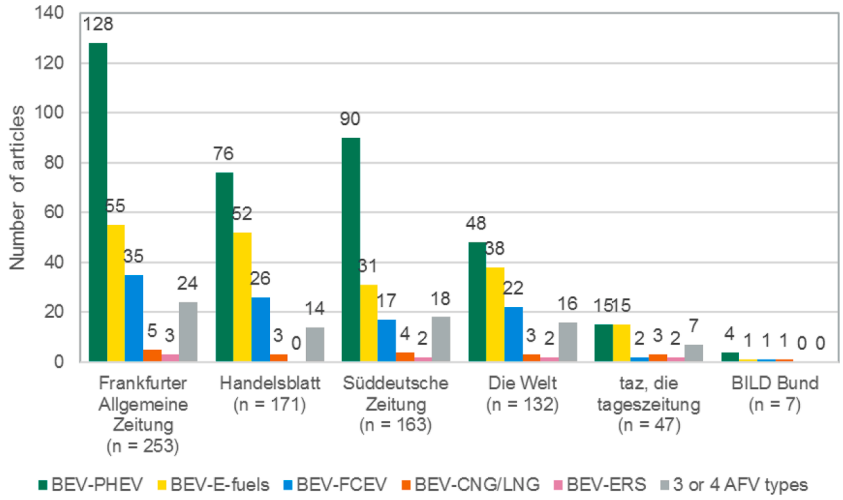


**Fig. 4.2-2.** Number of articles mentioning the most frequent AFV combination per newspaper.

**Table 4.2-2**
Sentiment analysis results for newspaper articles comparing BEV and FCEV technologies.

| No evaluation or comparison | BEV more positively evaluated | FCEV more positively evaluated | Both evaluated similarly | | |
|---|---|---|---|---|---|
| | | | Both positive | Both neutral | Both negative |
| | | | 11% | 5% | 1% |
| 31% | 22% | 30% | 17% | | |

*4.2.4. Contrasting attitude relations and comparative media coverage on BEV and FCEV*

The assessment of prerequisites shows that all three cannot be fulfilled by the articles including both BEVs and FCEVs. A quantitative assessment of media effects can therefore not be performed. A qualitative comparison of the findings of the survey and the media analysis provides first indications on their relationship. When both technologies are evaluated similarly in the analysed media coverage, both are evaluated as predominantly positive or neutral. This matches the positively correlated attitudes between the two technologies in the survey. In more than half of the articles including both technologies, however, one is favoured over the other. This matches the finding that, despite the overall parallel and positive tendency, attitudes between BEV and FCEV differ and a more positive attitude towards one of the technologies is only weakly connected to a more positive attitude towards the alternative. Finally, 58% of the articles in favour of one technology favour FCEV, while 42% favour BEV. This parallels the higher average attitudes towards FCEV in the survey. The findings also match the results of an additional survey item, which shows that for those expecting only one AFV technology to succeed in the future, BEV dominate but a significant share also expects FCEV to succeed alone (see Appendix D).

## 5. Discussion

This study has examined the effects of media coverage on attitudes to AFV technologies in Germany. Media attention to the topic of AFV technologies varies over time and between technology types, with BEVs receiving the most extensive and consistent coverage. The findings show that the cumulated, ubiquitous, and positively consonant coverage of BEV technologies is related to more positive attitudes towards BEV. This finding suggests that the effects of media coverage found in other empirical studies, can also hold true for studies of alternative technologies. Effect strengths of the media exposure variable are small to moderate, which fits the effects strengths generally found in individual-level studies of media effects (Arlt and Wolling, 2016). The chosen individual level analysis substantiates that this effect holds empirical weight and does not occur due to the potential ecological fallacies of earlier media effects studies at the aggregate level. Future research could, however, gain an even clearer picture through a time panel analysis. Additonally, the overall model fit could be improved by focusing on a more limited amount of technologies and including all technology-specific variables shown to significantly influence technology attitudes in previous research in the survey.

Furthermore, the findings show that individuals with positive attitudes towards one AFV technology are also positive towards other AFV options. For the weakest positive attitude relationship between BEVs and FCEVs, the analysed media coverage presents a positive but contradicting picture. Joint coverage of the two technologies is not consonant in terms of sentiments and both technologies are presented as more favourably than the other to a similar extent, suggesting to readers both an uncertainty as well as the necessity to make a choice between the two. The parallels indicate that a relationship between the comparative depiction in media and the attitudes towards both technologies are possible. However, it remains unclear whether attitudes towards both technologies would be affected by such a depiction or only attitudes of the more or less favourably portrayed technology and how strong the effect of such a comparative media coverage would be in quantitative terms. Overall, attitudes are not as clearly tilted towards BEV as one might

expect given their dominance in media coverage, the clear positive positioning of German car manufacturers on electric mobility over the last years, and the growing sales numbers. This means that AFV purchase decisions cannot be determined by attitudes alone. Due to the complexity of assessing reciprocal relationships of technologies on attitudes and the promising qualitative findings, additional future research on this topic is warranted.

The coverage frequencies of AFV technologies besides BEV and of the joint technology depiction show that there can be cases in which media coverage is not cumulated, ubiquitous and consonant. In such cases, individuals could be exposed to varying levels of positive or negative sentiments and might use different measures to form or adjust their attitudes. They could, for example, rely on previous experiences with similar technologies (Ammari et al., 2018), on peer feedback, or focus on different evaluation measures in media coverage, such as attributes or framings (Chernov and McCombs, 2019; Maurer, 2017; Scheufele and Tewksbury, 2007). According to the theories on these concepts, not only the frequency and direct appraisal of the technologies but also the attributes according to which the technologies are evaluated can have an effect on media recipients. An example would be the comparison of AFV technologies in terms of their environmental effects versus in terms of their effects on the economy. Future studies could incorporate such an additional level in the analysis with extended qualitative coding or through an automated frame analysis, for example based on topic modelling. The survey would then need to include items, which measure the pre-conceptions of the respondents towards specific frames, e.g. their environmental attitudes, as was done in parts by Arlt and Wolling (2016). Comparative framing experiments as they were done by, for example, Cacciatore et al. (2012b) could be a good starting point to examine such effects for infrequently and inconsistently covered technologies and technology combinations. They would also allow an assessment of the detailed effects of comparative technology depiction on the related individual technology attitudes.

For transitions research, this study has two key implications. First, transition theories acknowledge multiple actors and processes as important for change processes but recommendations frequently target policymakers. This study shows that the active and passive steering of a transition does not only happen at the policy-level. Future technology pathways, as a key part of many transitions, can also be shaped by other societal forces such as media coverage, which can influence individuals' technology attitudes. This underscores the importance of previous research that follows changes in collective technology expectations (Konrad et al., 2012; van Lente et al., 2013) and technology legitimacy as they are portrayed in media over time (Markard et al., 2016). Hype cycle studies have extensively discussed the reinforcing processes between actors and media in perceiving but also contributing to collective expectations. The findings on measuring such a process in this study support the point that media coverage can have a direct effect on recipients' attitudes and thereby influence their behaviour and ultimately transitions as a whole.

Second, transitions research should pay attention to media as a mediating force between powerful interests and the public. In addition to its effects, media is also influenced by actors who engage in so-called agenda-building (Maurer, 2017). Powerful organizations, such as automotive incumbents, whose views are reported on through interviews or re-phrased press releases, can use media channels to disseminate their positions. A connection to studies of discourses and power dynamics in sustainability transitions could be achieved by setting this quantitative study in context with a qualitative analysis of industry and government statements about interactions between AFV technologies and struggles over 'technology neutrality'. The combined results of studies addressing discursive struggles and media effects can then not only inform and benefit policymakers but also journalists and clarify their important role in transition processes.

## 6. Conclusion

In conclusion, the study finds that media exposure to AFV technologies can have an effect on individuals' attitudes towards these technologies. In comparison to the stronger psychological factors of environmental identity and car dependency, cumulated, ubiquitous, and consonant media exposure results in small to moderate effects, but shows a significant and positive impact. This is relevant because media coverage changes more frequently than psychological dispositions. The tracing of coverage peaks shows that coverage is frequently related to events. Societal actors wishing to influence public attitudes towards technologies could hence engage in agenda-building by initiating or commenting on such events to ensure that their favoured technological options gain a more significant spot on the media agenda. Journalists, on the other hand, have a gatekeeping function and could mediate such peaks through heterogeneity in their coverage.

Media coverage fluctuates and, as the analysis shows, differs in the attention it gives to certain technologies at a certain time. While experts or policymakers consider certain pathways to be most realistic or desirable, the media might pick up or amplify some pathways over others, lag behind the expert discourse in some aspects, or present different technology pathways in different outlets. This research has shown that such discrepancies can have a real impact on individuals' technology attitudes. For a successful transition towards a more sustainable transport system, monitoring and analysing who influences the media agenda and to what effect will therefore be a key task for researchers and policymakers.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A. Research case: alternative fuel vehicles (AFVs)

AFVs are vehicles which produce significantly lower emissions than the gasoline- and diesel-powered vehicles that have made up the status quo for the last 100 years. The term includes both vehicles that use alternative fuels such as biogas or Power-to-X fuels in a combustion engine as well as vehicles that use hydrogen and fuel cells or electricity stored in batteries to power an electric engine. Alternative terminology or synonyms for these technologies are: alternative vehicle (van Bree et al., 2010); alternative engine technologies (Dijk, 2014); (alternative) vehicle powertrains (Mirzadeh Phirouzabadi et al., 2020); alternative transport fuels (Sandén and Hillman, 2011); and low- and zero-emission vehicles (LEV and ZEV) (Bakker et al., 2012; Wesseling et al., 2015). In the German context, „Alternative Antriebe“ (alternative drives) is considered as the equivalent for AFV.

For cars, this study includes battery-electric vehicles (BEV), plugin-hybrid electric vehicles (PHEV), hydrogen or fuel cell electric vehicles (FCEV), biogas and natural gas vehicles (CNG/LNG), and vehicles powered by synthetic fuels (E-fuels). For trucks, the same vehicle technologies are included, with the addition of catenary trucks as one specific type of Electric Road Systems (ERS) since this technology is tested in field trials in Germany.

## Appendix B. Research design: linkage of relevant elements

The six most read daily national newspapers in Germany (“Leitmedien”) were chosen as the media category. Most readers of these newspapers live in cities (BDZV, 2014) - the population for the survey sample was accordingly matched to be representative for German cities with a population >100,000 with an even distribution over regions. The survey took place between August and September 2020. The time frame for the media analysis was set accordingly: media coverage between two years and up to two weeks before the survey was considered based on reasonably assumable media effects derived from literature, resulting in a time frame from August 2018 to July 2020 (Maurer, 2017). For a close match on an individual level, the survey was set up with questions on the frequency of a person’s usage of the six studied newspapers. Finally, both data collections focused on the topic of AFV technologies.

## Appendix C. Supplementary material multiple regression analysis

Table C1

**Table C1**
Correlations between all variables of the regression model.

| Variable | Media | gender | age | educ | job | env. ident | car.dep | tech.aff | knowl | drive. exp | attitude |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Media | 1.00 | 0.12** | −0.14** | 0.13** | 0.28** | 0.07* | .10** | - 0.01 | .22** | .27** | .18** |
| Gender | | 1.00 | .13** | .071* | 0.036 | −0.082** | 0.02 | .21** | .28** | .09** | .06* |
| Age | | | 1.00 | −0.068* | −0.196** | .11** | −0.05 | .08** | −0.004 | −0.13** | −0.11** |
| Educ | | | | 1.00 | 0.034 | −0.003 | 0.01 | .07* | .12** | .098** | 0.03 |
| Job | | | | | 1.00 | 0.01 | .16** | −0.15** | .196** | .29** | .19** |
| env.ident | | | | | | 1.00 | −0.20** | −0.01 | .09** | .07* | .25** |
| car.dep | | | | | | | 1.00 | .13** | .23** | .10** | −0.09** |
| tech.aff | | | | | | | | 1.00 | .22** | 0.01 | 0.013 |
| Knowl | | | | | | | | | 1.00 | .26** | .17** |
| drive.exp | | | | | | | | | | 1.00 | .22** |
| Attitude | | | | | | | | | | | 1.00 |

*Note.* media = media content weighted exposure score BEV*; educ = education; job = related job; env.ident = environmental identity; car.dep = car dependency; tech.aff = technology affinity; knowl = knowledge BEV* cars; drive.exp = drive experience BEV* cars; attitude = attitude BEV* cars; * BEV = placeholder for main model; question individually asked for BEV/PHEV/FCEV/Gas/e-fuels (drive experience excluding e-fuels).
Attitudes towards BEVs are significantly and positively correlated with the amount of BEV media exposure, being male, having a related job, stronger environmental identity, higher knowledge of BEV cars, and greater drive experience with BEV cars. Conversely, they are negatively correlated with age and car dependency, meaning that older respondents and those who feel they need a car to manage their everyday life have less positive attitudes towards BEVs. Correlations between the independent variables are as expected, except for a negative correlation between related job and technology affinity.

*Interpretation of media coverage effect strengths*

Individuals' attitude towards BEV increases by 0.1 Likert points (1 Likert point) for each increase of 1000 (10,000) in BEV media exposure, representing 1000 (10,000) more potentially perceived articles on BEV in the covered two-year span for a daily newspaper reader.

This would apply to a person reading the newspaper(s) in which the additional articles appear daily. For a usage below that, article numbers would have to increase accordingly (e.g. more than double for reading three times per week). With article numbers remaining constant, an increase of 1000 could also result from reading the analysed newspapers two more days per week. This is, however, not transmissible to larger numbers such as 10,000 as this factor of the composite exposure variable is limited to a maximum of seven days per week.

## Appendix D. Technology expectations

Table D1, Table D2

**Table D1**
Survey results on expectations towards future technology market interactions.[5]

| *Q34: What do you think will be the development in the car sector until 2030?* | Frequency | % |
|---|---|---|
| AFV technologies for cars will not succeed against petrol and diesel cars. | 379 | 21.9 |
| One AFV technology will succeed against all other car drives. | 253 | 14.6 |
| Several AFV technologies will succeed together and will be available in parallel. | 824 | 47.7 |
| Don't know. | 271 | 15.7 |
| *Sum* | 1727 | 100 |

**Table D2**
Results of filter question on technology expectation if one technology is expected to succeed over others.

| Q34 × 1: Which alternative fuel vehicle technology do you think will succeed against all other car drives? | Frequency | % |
|---|---|---|
| FCEV | 72 | 28.5 |
| BEV | 93 | 36.8 |
| PHEV | 53 | 20.9 |
| (Bio-)gas | 15 | 5.9 |
| E-fuels | 12 | 4.7 |
| Sum | 253 | 100 |

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