Factors influencing policy instrument choice(s): the case of fuel cell electric vehicles

R.P. Arp (3240959)
r.p.arp@students.uu.nl

Course: Master Thesis (GEO4-2239X)
Master program: Innovation Sciences
Supervisor: dr. J.H. Wesseling (j.h.wesseling@uu.nl)
Second reader: prof. dr. M.P. Hekkert (m.p.hekkert@uu.nl)

Date: July 27, 2017
Number of words: 15818 words

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Universiteit Utrecht

International Partnership for Hydrogen and Fuel Cells in the Economy

Acknowledgements

I would like to thank my supervisor Joeri Wesseling for his helpful and inspiring comments during this entire thesis project. Comments from Tim Karlsson (IPHE), Mandy Willems, Wilco Fiechter (RWS) and Marko Hekkert (UU) are gratefully acknowledged. Second, I would like to thank my girlfriend and parents for their never-ending support, helpful insights and words of encouragement. Last but not least, I would like to thank all the people who participated in the interviews and send out information. Without your valuable insights and information this project would not have been possible.

Disclaimer

The views and opinions expressed in this thesis are those of the author and do not necessarily reflect the official policy or position of any government agency or organization involved in this research.

Abbreviations

BEV	battery electric vehicle
CAFCP	California Fuel Cell Partnership
CHFCA	Canadian Hydrogen and Fuel Cell Association
CPA	corporate political activities
EAFO	European Alternative Fuels Observatory
EU	European Union
FCEV	fuel cell electric vehicle
GDP	gross domestic product
GHG	greenhouse gases
HARC	Hydrogen Analysis Resource Centre
ICE	internal combustion engine
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
VoC	Varieties of Capitalism
ZEV	zero-emission vehicle

Table of contents

Abstract

Fuel cell electric vehicles (FCEVs) can play an important role in the transition towards sustainable mobility. Their deployment however requires technological and system changes which public policies can help facilitate. This research looks at which policies are in place for these vehicles in industrialized countries between 2012 and 2016 and tries to uncover which factors influence how specific policy instruments are chosen. For this purpose, a theoretical framework was setup based on scientific literature on policy instrument choice in general as well as for the specific case of zero-emission vehicles. To analyse this, a mixed-methods approach was taken where a quantitative analysis of OECD countries together with qualitative, in-depth analysis of nine countries was done. This in-depth analysis was done by reading policy documents as well as by doing interviews with policy makers. The quantitative analysis showed that the importance of a countries car industry as well as the number of FCEVs deployed are indicators for the amount of governmental RD&D subsidies provided. The qualitative analysis revealed that the policy goals and underlying rationale, who is responsible for their formulation and implementation, the role of car manufacturers in this process, which other policies have been previously been implemented and which national resources a country has, are important factors that influence policy instrument choices. These findings are important because this creates a better understanding of why countries choose specific policy instruments which in turn can help future formulation and implementation of policies and help the transition towards new and sustainable technologies such as FCEVs.

1. Introduction

Most economies are heavily dependent on fossil fuels which in turn have detrimental effects on the environment in terms of pollution and loss of biodiversity (IPCC, 2007). The burning of fossil fuels causes emission of air pollutants and greenhouse gases (GHG) which in turn contribute to extreme weather conditions, rising sea levels and heating of the planet (IPCC, 2013). Carbon dioxide (CO_2) is one of the main contributors and accounts for 65 percent of the total GHG emissions (IPCC, 2014). Furthermore, fossil fuels have to be imported from politically unstable countries which might cause problems for future fuel supply (EIA, 2016). Thus, for both energy security reasons as well as ensuring a sustainable future, the transition towards a new, decarbonized energy system is paramount (Markard et al., 2012).

A major contributor to GHG emissions is the transportation sector which accounts for 14 percent of the total global GHG emissions (IPCC, 2014). While emissions from energy production and other industrial activities seem to stabilize, GHG emissions of the transport sector are still increasing, even in high-income countries (EEA, 2012). Furthermore, the transportation sector is heavily dependent on oil imports which decreases energy security. In order to move towards a decarbonized energy system, a major transition in this sector is required (Lior, 2012). This transition requires the move towards more efficient and less polluting technologies which can be achieved by introducing so called zero-emission vehicles (ZEVs) (Lior, 2012). Most popular are battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Another type is fuel cell electric vehicles (FCEVs) which generates electricity using hydrogen which then powers the car (Pollet et al., 2012). This type of vehicle has potential as compared to BEVs because of their extended range and shorter refuelling time (McKinsey, 2010). There are however also some problems with this type of vehicle, mainly because of higher infrastructure and capital costs (Romm, 2006) caused by the vehicle being in the early stages of market introduction (ICCT, 2016).

Zero-emission vehicles differ in terms of drivetrain and infrastructure requirements as compared to internal combustion engine (ICE) vehicles and require technological and system changes (Wesseling, 2016). Such changes also require a change in actors, institutions and their interactions where the government, using public policy, can facilitate these early transitional processes (Flanagan et al., 2011). While a number of public policy studies have addressed single policy interventions and the interaction between different interventions, the wider context in which these instruments are formulated and implemented is often neglected (Kern et al., 2017). Understanding this context however can help explain why specific policy instruments are formulated and implemented within countries (Rogge and Reichardt, 2016). This in turn can help create a better understanding of the transition process of early-stage, radically new and sustainable technologies and how this process differs across countries (Salmenkaita and Salo, 2002).

This is especially relevant for the case of FCEVs since this is a technology that is in the early stages of market introduction. These radical system innovations require new types of policies aimed at achieving systemic changes (Hekkert and van den Hoed, 2006; Weber and Rohracher, 2012). However, differences between countries and their context make it difficult to apply the same specific policy instruments in similar countries. Analysis of these contextual factors is therefore important to be able to understand when and under what circumstances policies are formulated and implemented (Borrás and Edquist, 2013). This understanding in turn can improve adoption of FCEVs. From this follows the following research question:

Which factors can help explain differences in policy instrument choice for fuel cell electric vehicles across industrialized countries between 2012 and 2016?

This paper seeks to create a better understanding of what contextual factors influence policy instrument choice. Although policy evaluation is outside the scope of this research, understanding the complexity of the policy making process is necessary to be able to better evaluate these policies and whether they achieve their set goal (Salmenkaita and Salo, 2002). Better understanding and evaluation in turn can help improve policies for the adoption of FCEVs specifically or ZEVs more generally and in turn reduce GHG emissions. As such, the societal contribution of this paper is to improve the introduction of ZEVs and as a result prevent further harm to the planet and our living environment. The focus is on industrialized countries because data from emerging countries is not always available or reliable. Furthermore, only the past five years will be analysed because most industrialized countries have only recently started to formulate and implement policies that support FCEVs.

This thesis is outlined as follows. Section 2 gives an overview of the theoretical concepts that can help explain how and what underlying factors shape policy instrument choice. Section 3 describes the research methodology as well as the operationalization of the theoretical concepts. Section 4 reports the results of this research. In section 5, the implications and limitations of the results are discussed. Section 6 concludes.

2. Theory

2.1 Dependent variable: policy instruments

Policy instruments are defined as tools (Salamon, 2000) used by a governing body to achieve specific policy objectives (Howlett and Rayner, 2007). These policy instruments need to be adaptable to changing circumstances such as changing system needs. The literature generally distinguishes three **types** which are regulatory, economic, and soft policy instruments (Borrás and Edquist, 2013). *Regulatory* instruments *"use legal tools for the regulation of social and market interactions"* and are obligatory in nature. *Economic* instruments provide monetary incentives or disincentives to regulate specific social and economic activates. *Soft* instruments are voluntary and provide *"recommendations, make normative appeals or offer voluntary or contractual agreements"* (Borrás and Edquist, 2013, p.1516). Next to these types of instruments, their **focus** can also differ. This relates to whether the target of the policies is *technological development (supply-side)* or *market deployment (demand-side)* (Foxon and Pearson, 2008). An example of a regulatory, supply-side instrument is intellectual property rights, while purchase subsidies are an example of economic, demand-side instruments. In total, there are thus six different options when choosing policy instruments. Often however, instruments are not used individually but are combined with other instruments in an **instrument mix** to achieve a predefined policy goal. This instrument mix is defined as a *"set of different and complementary policy instruments to address the problems identified"* (Borrás and Edquist, 2013, p.1514). Several factors influence policy makers when choosing policy instruments for the formulation and implementation of policies. These choices often depend on differences between countries and time-periods (Borrás and Edquist, 2013) which is discussed in more detail below.

2.2 Independent variables: factors influencing policy instrument choice

Now that a policy instrument is defined, it is important to distinguish factors that can help explain differences in policy instrument choice. These factors relate both directly to the used policy instruments (policy goals and rationale) as well as more contextual factors such as economic interest and dispersal of power. They have been chosen after carefully studying scientific literature on policy instrument choice in general as well as for the specific case of zero-emission vehicles. The factor policy goal is chosen based on work, among others, by Borrás and Edquist (2013). The factor policy rationale is chosen based on work done by Laranja et al. (2008) and Weber and Rohracher (2012). The varieties of capitalism and economic interest concepts are chosen based on work by Wesseling (2016). The concept of political influence strategies is chosen based on work by Wesseling et al. (2015). The concept of previously implemented policies is chosen based on work by Kay (2006). The concepts of dispersal of power and national resources are chosen based on work by Borrás and Edquist (2013).

2.2.1 Policy goals

The choice for policy instruments should be done in relation to the actual problems identified as well as the main causes of this problem (Borrás and Edquist, 2013). This requires the setting of clear policy goals. A policy goal is defined as what the policy objectives are together with the concrete targets that are set (Howlett, 2009; Tuominen and Himanen, 2007). An example is the reduction of GHG emissions the European Union (EU) is trying to achieve. Here, the objective is to reduce emissions while the concrete goal or target is to reduce 20% of GHG emissions by 2020 (EU, 2013). Policy goals can be set to achieve different types of objectives, namely environmental, social or economic (Rogge and Reichardt, 2016). Examples are reducing greenhouse gas emissions, supporting economic growth, creating jobs or become independent from other countries in terms of fuel supply. It is expected that the formulation and implementation of FCEV policies is dependent on the policy goals that are set. For

example, FCEVs can be necessary to reduce GHG emission from the transport sector but might also be of importance for maintaining or developing a leading position in automotive technologies. Uncovering the underlying objectives and targets of these policies can therefore help uncover why specific policy instruments supporting FCEVs were chosen.

2.2.2 Policy rationale

Policy rationales *"articulate, problematize and justify the need for intervention and outline the logic through which that policy intervention is expected to lead to the intended outcomes"* (Laranja et al., 2008, p.823). A policy rationale is thus about the justification for why an intervention is necessary and serves as the basis for action. Intervention can only be deemed necessary if something is identified as a problem or failure (Weber and Rohracher, 2012). Policy interventions are sometimes deemed necessary because of the identification of *market failures*. This concept is about the inefficient allocation of resources where individual, self-interest benefits outweigh the societal benefits. Intervention in this case can be necessary because the societal benefits are supposed to outweigh individual benefits (Arrow, 1962). This view has however changed because solving market failures to support economic growth does not deal with challenges related to more transformative changes (Alkemade et al., 2011). Here, more systemic failures are seen as the basis for action (Smits et al., 2010). Two different types of systemic failures have been identified, namely structural and transformational system failures. Solving s*tructural system failures* relates to optimizing the current innovation system by supporting interaction between actors and by for example improving cooperation between firms and research institutes (Woolthuis et al., 2005). *Transformational system failures* are about completely transforming the system by for example heavily regulating or phasing out old technologies while at the same time supporting new technologies (Weber and Rohracher, 2012). It is expected that different failures and thus why intervention is deemed necessary will lead to choosing of different types of policy instruments, e.g. regulatory, economic or soft. The identification of market failures could lead to choosing for either economic or regulatory policy instruments that compensate for under investments by either supplying capital for knowledge development (Box, 2009) or setting up of specific protection and incentive structures (Hauknes and Nordgren, 1999). The identification of structural system failures could lead to choosing similar instruments as in the case of market failures but with the addition of using soft policy instruments to improve and stimulate cooperation between different actors (Woolthuis et al., 2005). Similarly, the identification of transformational system failures could also lead to choosing for all three types of policy instruments as *"single policy instruments are not sufficient to provide the necessary guidance and direction to innovation for transformative change"* (Weber and Rohracher, 2012, p.1043)

2.2.3 Varieties of capitalism

This is a concept where, based on the relationships between different actors (e.g. industry, governments etc.) within national context, different political economic systems can be identified (Hall and Soskice, 2001). While this concept encompasses a broad number of topics including the legal system, income distribution and employment, the main focus here is on how these three distinctions influence the role the government takes when it interacts with other actors and formulates and implements policies. Schmidt (2002), as opposed to the two economic system models of Hall and Soskice (2001), argues that there are three ideal-typical models. The first one is the *market* capitalism type where the government allows for the market to operate autonomously and lets economic actors be free to choose the direction and focus of their economic activities. The second type is *managed* capitalism where the government is enabling and encourages economic actors to operate and coordinate their economic activities among each other and together with the government. The last type is *state* capitalism where the government *"organizes cooperation among different economic actors and directs their economic activities"*

(Schmidt, 2002, p.122). In this vein, state capitalism countries could be the most active in intervening with economic actors and activities as compared to managed capitalism countries. In turn, managed capitalism countries could be more active in regulating economic actors and activities as compared to market capitalism countries.

By comparing these different political economic systems, a better understanding of the nature of transitions can be achieved (Challies and Murray, 2008; Hay, 2004) and can provide insight into the role of national institutional context on newly developing technologies (Mikler and Harrison, 2012). This distinction has however rarely been used to study innovation or environmental policies across countries (Wesseling, 2016) where only studies of the US have shown that highly regulatory industrial policies are in place (Block, 2008; Lazonick, 2011). Using this concept can be especially revealing for the case of FCEVs since early market technologies often involve different types of failures which need to be overcome by policies to make and keep the technology viable (Kemp et al., 1998; Sandén and Azar, 2005). In this case, it is expected that stricter regulation on economic activities and actors (e.g. state capitalism) make it more likely that more and stronger policies are in place in support of FCEVs.

2.2.4 Economic interest

Domestic industries are of importance for countries because they create jobs or lead to a competitive advantage on the international market necessary due to globalization (D'Costa, 2009). Therefore, countries often setup innovation policies that support their domestic industries which is a concept called *economic nationalism* (Clift and Woll, 2012). Especially relevant for the case of FCEVs are policies setup in support of the car industry as investing early on in such a new technology is the best way to achieve a competitive advantage on the international market (Galvin et al., 2015). These policies will mainly focus on supporting the innovative capabilities of domestic car manufacturers which in the case of India meant investments by the state in the industry as well as deregulating technology transfer requirements and production limiting rules (D'Costa, 2009). As such, it is expected that if the car industry is bigger in a country, more policies stimulating the production and development of FCEVs will be present.

2.2.5 Political influence strategy of car manufacturers

Incumbent car manufacturers might oppose the introduction of specific policies focussing on regulating their activities. Alternatively, policies might be introduced for FCEVs only and thus might have a negative impact on ICE producing firms. In both instances, these policies negatively affect ICE producing firms (Wesseling et al., 2015). As such, they will often try to influence the policy formulation and implementation process which has been named corporate political activities. These activities are usually employed by firms to strengthen their competitive advantage under strongly regulated environments (Hillman and Hitt, 1999) where the firm tries to maintain the status quo or to create value by making use of early mover advantages. Car manufacturers can make use of *defensive* political influence strategies to maintain the status quo or *proactive* strategies to make use of early mover advantages (Oliver and Holzinger, 2008). Two types of defensive strategies are *opposition*, oppose new policies to protect incumbent technologies, and *slowdown,* slowing down implementation of new policies to be able to first create value from new technologies themselves. Two types of proactive strategies are *support*, supporting new policies because of advantage for the firm, and *progressive*, stating the need for increased stringency of regulation because it creates an advantage for the firm (Wesseling et al., 2015). For the specific case of FCEVs, the introduction of policies for FCEVs could threaten incumbent car manufactures where they may try to actively influence the policy formulation and implementation process. Therefore, it is expected that if car manufactures are more in favour of FCEV technologies, they will employ proactive rather than defensive political influence strategies.

2.2.6 Previously implemented policies

When new policies are formulated and implemented, interaction with other previously implemented policies can have both restricting as well as enabling options for future policy instrument choices (Kay, 2006). This is because policy makers are not completely free in their policy choices because of path-dependence where previous choices have become institutionalized (Howlett and Rayner, 2007; Kern et al., 2017). Furthermore, this dynamic often gets more complex over time as it is easier to formulate and implement new policies rather than remove the ones that have become institutionalized (Flanagan et al., 2011). Looking at previously implemented policies, it is important to distinguish whether the new policy instrument is complementary or incompatible with previously implemented policies. *Complementary* policy instruments can be seen as mutually beneficial for the policy goal while *incompatible* policy instruments hamper the achievement of this goal (Gunningham and Sinclair, 1999). For the specific case of FCEVs this could mean that instruments are in place as additional support and are thus complementary. An example is RD&D subsidies as well as financial incentives for consumers. There can thus also be counteracting instruments which are incompatible. An example is fossil fuel subsidies which leads to lower prices for gasoline. This in turn might make buying an ICE vehicle more attractive and thus hampers the adoption of alternative fuel vehicles like FCEVs. Therefore, it is expected that interaction between previously implemented policies and new ones has an influence on whether FCEV supporting policies can be successfully implemented.

Also of importance when looking at previously implemented policies is whether they focus on a specific technology or are technology neutral. Policies that focus on a different technology could hamper the adoption of other technologies not supported by the policy (Azar and Sandén, 2011). For the specific case of FCEVs this means that policies that apply to BEVs but not to FCEVs could hamper the adoption of FCEVs as there is not support for this technology by the policy. Uncovering whether there is a technological focus of previously implemented policies can reveal whether policies focusing on FCEVs are complementary or incompatible.

2.2.7 Dispersal of power

This concept looks at which level(s) of government and which ministries is or are responsible for the formulation and implementation of policies. These powers can be divided vertically between national, regional and local as well as horizontal, between different ministries (Bache and Flinders, 2004). Policies are usually formulated and implemented at the national level but this can also be done at the supra or subnational level (Flanagan et al., 2011). For example, there might be regulations from the EU that hamper the formulation and implementation of the policies. Furthermore, the level and responsibility of the formulation and implementation of policies also changes over time (Rogge and Reichardt, 2016). This is especially the case for European countries where the EU often sets the overall target, the formulation of a policy framework is done at the national level and the implementation is done at the regional or local level (Lepori et al., 2007; Smith, 2004). When innovation policy instruments are located at different levels of government, this could lead to inconsistencies across different state structures (Borrás and Edquist, 2013). For example, if too many different governmental levels are responsible for the formulation and implementation of policies and power is thus dispersed, the successful formulation and implementation of policies could be hampered because of bureaucracy. For the specific case of FCEVs this could mean that once power is dispersed between different governmental levels and ministries, this could hamper the implementation and success of policies in support of FCEVs.

2.2.8 National resources

Next to the factors identified above, several other factors can influence the choice for specific policy instruments because the specific and unique nature of innovation systems together with socio-political and historical contexts often differ between countries. This leads to different national policy styles and could lead to choosing different policy instruments (Borrás and Edquist, 2013). These different national resources can be characterised by looking at industrial activities or natural resources that influence choices for specific policy instruments. Here, the presence of these activities or resources creates unique opportunities for countries in using a certain technology to fulfil certain policy goals. An example for the specific case of FCEVs is when a country wants to reduce emissions coming from the transportation sector and chooses to focus on these vehicles because it has industrial activities where hydrogen is a by-product that can be used as fuel. Thus, understanding of such meta-level factors can provide context and help understand why a country chooses to aim for FCEVs and use policies to stimulate development, production and/or deployment of these vehicles.

2.3 Conceptual model

Interaction between some of the factors is also possible. For example, a bigger car industry could lead to the government regulating their activities because of its importance for the national economy. This could also mean that previously implemented policies are in place. More regulation in turn could mean that car manufactures will employ more active political influence strategies because these regulations could hamper their economic activities. Assessing these interaction effects is however not within the scope of this research as the large number of independent variables alone takes up all the time available for doing this research.

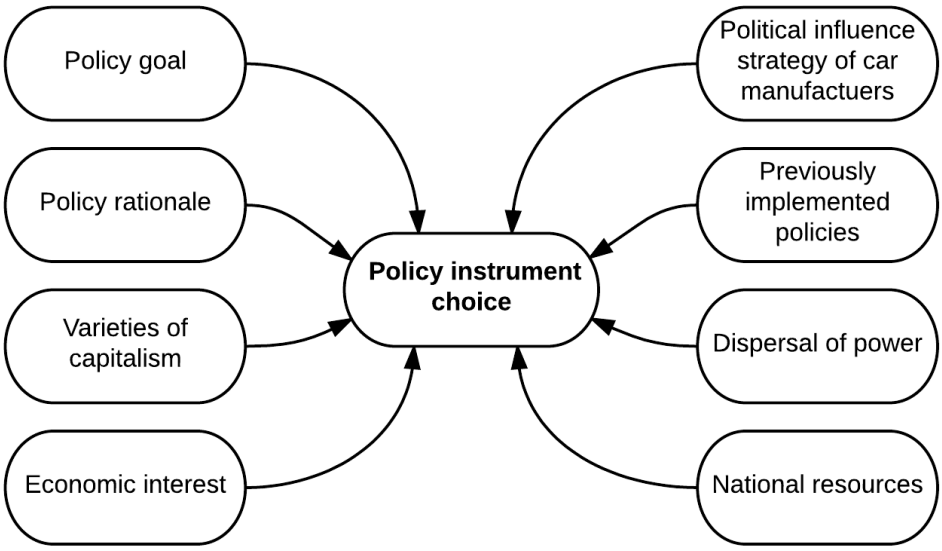

Figure 1. conceptual model

3. Research methodology

3.1 Research design

The nature of this research is *deductive* because theoretical insights from scientific literature were used to derive the independent variables (Bryman, 2012). Part of this research was also *inductive* since there is still a gap in the literature regarding which factors influence policy instrument choice. To identify potential factors, open and explorative questions were asked to the interviewees. The purpose of this research was to empirically explain which factors influence the choice for specific FCEV policies. This research therefore has an *explanatory* function (Oost, 2006). This research employed a mixed methods approach that combines quantitative and qualitative methods of analysis (Creswell, 2003). This was most suitable because the variables varieties of capitalism and economic interest are best assessed statistically, in part because previous studies took the same approach (see for example Wesseling (2016)). The other variables were however best assessed qualitatively and provided in-depth insight into the process with which policy makers choose different policy instruments.

Since factors explaining differences between countries were assessed and thus comprised of multiple cases, a *multiple-case study design* was most appropriate. Furthermore, this approach incorporates context and allowed for the identification of additional factors influencing policy instrument choice next to the ones identified from scientific literature and discussed here (Yin, 2003). Since most policies are formulated and implemented at the national level, the *unit of analysis* was countries. In theory, every country in the world might have policies in place for FCEVs. However, data from emerging countries is not always available nor as reliable. Therefore, only industrialized countries were included in this research. For this purpose, all 35 countries who have joined the OECD were included and constitutes the *population*. This includes countries who are both active and not active in developing and/or deploying FCEVs. As such, next to uncovering specific FCEV policy instrument choice, this helped uncover why certain countries chose not to specifically aim their policy instruments at FCEVs.

3.2 Operationalization and data collection

Data was collected from policy documents, internet searches and databases as well as by conducting interviews. By making use of different sources, triangulation was applied which increases the creditability and validity of the results. The collected data was used for different purposes. First, to provide an overview of the entire population of OECD countries in terms of FCEV activities and policies. This data was useful for the selection of a sample on which a more in-depth analysis was done by reading policy documents and doing interviews. Additional data was gathered and used for the quantitative analysis (varieties of capitalism and economic interest) of this research. Once the cases were selected and prior to conducting the interviews, policy and other relevant documents were extensively studied to have knowledge on what is specifically happening in these countries in terms of FCEVs. This was also done as to not ask questions on which information was already available. Furthermore, if for example a specific political influence strategy was identified from these documents, further elaboration or explanation was asked during the interview.

Because of the availability of interviewees and the time required for triangulation of the data resulting from these interviews, data on nine countries was collected and analysed. In choosing the respondents for these interviews, the *key informant approach* (Morgan and Hunt, 1994) was used where the most knowledgeable people with regards to FCEV policies were chosen. More specifically, the most knowledgeable people are the ones who are active in formulating and implementing FCEV policies. Since the focus of this research was on the national level, the *unit of observation* was policy makers active on a national level. Since there was not enough time and money to visit all the key informants, interviews were conducted via telephone. The aim was to interview two people, one who is active on a

strategic level and one on a more practical level, per country. This approach was best because it allowed for gaining insights into the policy formulation (strategic) as well as implementation (practical) process. For this purpose, a *semi-structured* interview guide was set up. This guide was flexible and enabled follow-up questions or changing the order of the questions if necessary. Interviewees received the interview guide prior to the interview so they knew what to expect. In order to be able to properly answer the research question, the interview guide follows the theoretical concepts as discussed in the theory section (Bryman, 2012). The interview guide is attached in Appendix B.

3.2.1 Case selection and quantitative analysis

As discussed previously, data was gathered to be able to select cases for in-depth analysis as well as being able to quantitatively assess two of the independent variables used in this research (varieties of capitalism and economic interest). Table 1 provides an overview of the concepts on which quantitative data was gathered as well as their operationalization and potential data sources. They provide an overview on whether and how active each country is in terms of deployment of FCEVs, the diffusion goals for FCEVs, the economic interest and capitalism type of countries and which incentives are provided for FCEVs. Each concept is discussed in more detail below. In most instances, web searches were necessary to find additional information and to be able to triangulate already available data. The search terms defined below were first used in English followed by the specific country on which information was necessary. If this did not lead to any useful information, the English search term was translated to the native language of the country using Google Translate. If this did not result in any useful information, "no data" was mentioned in the dataset.

Table 1. Operationalization case selection/quantitative analysis

Concept	Measurement	Data source
Deployment activities	Number of FCEVs as percentage of total vehicle fleet [1]	HARC, EAFO, national policy, IPHE documents and OICA
	Total number of active and planned hydrogen refuelling stations (HRS) [1]	NetInform and HARC
Deployment goal	Number of FCEVs deployed by 2020 [2]	National policy and IPHE documents
Economic interest	Turnover of car industry as percentage of the national GDP [2]	OICA and World Bank
Varieties of capitalism	Market, managed or state capitalism [2]	Schmidt, 2002 and 2003, other scientific literature
Incentives	Incentives provided for the production and development (supply-side) as well as the purchase and/or use (demand-side) of FCEVs [1]	EAFO, national policy and IPHE documents

The concept of **deployment activities** and the used measurements are based on work by Sierzchula et al. (2014) who, in their study on electric vehicle policies, showed that these measurements are good indicators of the deployment activities undertaken by countries. Data on the *number of FCEVs* was gathered from the European Alternative Fuels Observatory (EAFO, 2017a) (for Europe) and the Hydrogen Analysis Resource Centre (HARC, 2016a, 2016b) (for the US, Asian and Latin American countries). Additional data on European countries not included by the EAFO was also gathered from the HARC. However, EAFO was the preferred source because their information is more recent (February 2017 as opposed to December 2016). If no information was available for a specific country, web searches were used (search terms: *Fuel cell electric vehicles [country], HFCV/FCEV [country], Hydrogen cars [country], Number of hydrogen fuel cell electric vehicles, deployment FCEVs [country]*). To be able to compare the number of FCEVs across countries, the number of FCEVs per country was converted to a percentage of the total vehicle fleet. Data on the total vehicle fleet was gathered from the

OICA and included all vehicles in a country in the year 2014. Data on the *refuelling infrastructure* was gathered by making use of the worldwide map by NetInform. This is the best and most reliable source since it is updated on a regular basis and provides worldwide information. This information was cross-checked with information on refuelling stations from HARC.

The concepts and measurements of deployment goals, economic interest and capitalism type are based on work by Wesseling (2016). **Deployment goals** of individual countries were gathered by making use of IPHE documents and by searching the web (search terms: *deployment target/uptake target/goals [FCEVs/hydrogen vehicles]*) to find policy documents stating specific goals for FCEVs. Only diffusion goals were included when FCEVs were explicitly mentioned. While some countries set goals for total number of ZEVs, it is not always specified what the contribution of FCEVs to that total number is and these were therefore not included.

Data on the **economic interest** concept came from two different sources. *Turnover of the car industry* per country was gathered from the OICA (2015). Eight countries from the population are not included by the OICA and web searches were used to lookup the turnover for these individual countries (search term: *turnover automotive/car/auto industry [country]*). Data on *GDP per country* was gathered from the World Bank for the year 2015 and converted to euro's using the conversion rate of 31/12/2015.

Capitalism type per country was based on the work of Schmidt (2002) and Schmidt (2003). If countries were not mentioned in these two books, web searches were used to find additional literature (search term: *varieties of capitalism [country]*). Literature research however showed that East Central European countries should be divided into yet another form of capitalism as they *"lack easy categorization into standard capitalist categories"* (Jackson and Deeg, 2012, p.1119) and *"have experienced a specific type of economic and political transformation and occupy a different position in the capitalist world economy"* (Nölke and Vliegenthart, 2009, p.671). Therefore, the countries Czech Republic, Estonia, Hungary, Latvia, Poland, Slovak Republic and Slovenia were labelled as East Central European. This was also done for the two Latin American countries, Chile and Mexico, that were included in the population. Latin American countries belong to yet another, albeit different, type of capitalism which has similarities with all three different types of capitalisms (Bizberg, 2014; Schneider, 2009). These two countries were therefore labelled Latin American.

The **incentives** concept relates back to the dependent variable in this research and tries to provide a general overview of the incentives used in countries. As discussed in the theoretical section, incentives can be subdivided according to their type (regulatory, economic or soft) and focus (supply-side and demand-side). While assessing all these different types of policies would provide a full overview of the policies in place for FCEVs, only financial instruments were assessed here. In line with other scientific literature and reports, such an approach was best because these types of incentives *"are easily quantifiable and extensively used by national governments"* (Wesseling, 2016, p.4). Furthermore, it was important to distinguish which policies could be deemed applicable to FCEVs and which to include when assessing policies used in different countries. This was relevant because some policies, for example purchase subsidies, often focus on a specific technology, while others, like emission based vehicle taxes, are technology neutral. Relevant in this research were both policies specifically focusing on FCEVs as well as ZEV policies. This is because FCEVs are also zero-emission vehicles as they do not produce any emissions and thus belong to the ZEVs category. Therefore, it was assumed that all policies focusing on these types of vehicles also include FCEVs. Furthermore, only looking at specific FCEV policies would not give a complete picture of the policies in place for FCEVs since most ZEV policies also apply to FCEVs. Policies focusing on EVs were however excluded. While FCEVs are electric vehicles with a fuel cell, the definition of EVs almost always pertains to BEVs or PHEVs. This becomes clear from reports by the ICCT (2016) and IEA-HEV (2016), who states that a *"battery electric vehicle (BEV) is considered to be a synonymous term"* to electric vehicles.

Data on the **demand-side incentives** per country was gathered by making use of EAFO (2017b), IPHE documents and by searching the web (*search terms: incentives [hydrogen/FCEVs]*) to find policy documents stating specific policy instruments used for FCEVs. Also used were reports on electric vehicles, zoom in on a specific country within the report and see whether the policy instruments for EVs also applied to FCEVs. These documents were found by using web searches (*search terms: incentives [electric vehicles/zero-emission vehicles*). Incentives were seen as applicable to FCEVs if they were explicitly mentioned, if they applied to all zero-emission vehicles or when "alternate" next to BEV and PHEVs was mentioned.

Data on **supply-side incentives** and thus RD&D subsidies was gathered by making use of the IEA RD&D database. The IEA database was chosen because policy documents rarely mention which part of the funding applies to FCEVs specifically. Therefore, all RD&D subsidies from the government for hydrogen and fuel cells were seen as relevant and included. While the IEA does include RD&D budgets for the years 2015 and 2016, not many countries have provided data for these years. In order to properly compare the countries, the years 2015 and 2016 were left out of the dataset.

3.2.2 Qualitative analysis

As discussed in the previous paragraphs, data was also gathered by making use of policy documents and by conducting interviews. The operationalization table attached in appendix A shows the different theoretical concepts identified in the literature as well as their indicators and potential data sources. These indicators were used to setup the interview questions and code the concepts once the interviews were conducted. In order to see the factors influencing policy instrument choice, it was first necessary to identify which policy instruments are actually used. Therefore, *policy instruments* were measured by looking at what types and what the focus of the policy instruments used in a country are and how these instruments are combined in an instrument mix. *Policy goals* were measured by looking at what objectives are set as well as the concrete and types of targets chosen. Furthermore, uncovering which actors and processes are targeted could create a more specific understanding of the policy at hand. *Policy rationale* was measured by uncovering which failures policy makers identified in their country and thus why intervention is deemed necessary. The *political influence strategies* employed by car manufacturers were measured by looking at which of the four different subtypes are most applicable to the strategies of car manufacturers employed in a country. *Previously implemented policies* were measured by looking at policies in place for all types of vehicles within a country including BE and ICE vehicles. Such a scope was best because policies for these types of vehicles also influence FCEV policy instrument choice. At the same time, such a scope was still specific enough so that it was possible to establish the relationship between the different policy instruments. Looking at whether these policies are complementary or incompatible could uncover why specific policy instruments for FCEVs work in some countries but not in others. *Dispersal of power* was measured by looking at where policies for FCEVs are formulated and implemented, who is responsible for them and who takes initiative. Lastly, *national resources* were measured by looking at the industrial activities and natural resources within a country to assess whether these influence on policy instrument choices.

3.3 Case selection

Selecting cases where there is variation across all variables would have led to a very large number of cases. Therefore, selection was based on the presence or absence of incentives as well as the types (supply-side and demand-side). This was important because policy instrument choice was the variable to be explained in this research and thus required some differences between countries in terms of which policy instruments were chosen. Variation in the other variables was also necessary and therefore, as much variation between the cases was strived for. For example, the sample included countries of all

different types of capitalism, different car industry sizes and deployment targets and activities. This was important because these variables could explain why different incentives were chosen. An overview of the gathered data on the entire population can be found in table 3 in section 4.1.

Unfortunately, for some countries, data was missing for several variables. If a country had data missing for three or more variables, it was excluded from the sample. This was done because it is unlikely that the necessary information for an in-depth analysis could be obtained. This led to the exclusion of Chile, Estonia and Israel and led to the population having 32 countries.

The gathering of data revealed several interesting cases. First was **Canada**, which is one of the few countries which has an above average car industry while still being well below the deployment average and explicitly not setting a deployment goal. Furthermore, while a purchase subsidy is given, this only applies to some regions of the country and is not implemented at the national level (CEVforBC, 2016). However, they do provide large amounts of RD&D subsidies. This case could reveal why countries that have a big car industry, invest in RD&D but do not invest in the deployment of these vehicles.

Another case like Canada was **Belgium**, which also has an above average car industry. They however differ in the incentives used. Here, Belgium provides only demand-side incentives while Canada only uses supply-side incentives. Furthermore, Belgium belongs to the managed capitalism type while Canada belongs to market capitalism type. Lastly, Belgium has set a deployment goal while Canada has not. This case could reveal why countries with similar car industry sizes and deployed FCEVs still choose to focus on either supply or demand-side incentives. Here, Belgium could reveal why an above average car industry does not necessarily mean high supply-side incentives as expected from the economic interest concept.

Norway was another case which is well above the deployment average, has no car industry and provides both supply and demand-side incentives. They have however not set a deployment target. This was interesting because Norway is the country with the highest deployment of BEVs (ICCT, 2016). One could therefore argue that they would also be very willing to invest in FCEVs next to BEVs and thus set a deployment target. This case could reveal why BEVs are preferred over FCEVs and could help identify potential pitfalls for FCEV adoption.

the Netherlands was another case which is above the deployment average and has a very small car industry. Like Norway, the Netherlands also has a high number of BEVs (ICCT, 2016). They however differ in the incentives used where the Netherlands has only demand-side incentives while Norway has both supply and demand incentives. Furthermore, their demand-side incentives differ where the Netherlands mainly focuses on a direct purchase subsidy while Norway choses tax incentives and non-financial incentives like free access to toll roads (IPHE, 2011). Therefore, also selecting the Netherlands could reveal the underlying reasoning for choosing these incentives and why they differ from Norway.

Iceland provides the widest variety of supply-side incentives (5 in total) of the entire population while still having deployed no vehicles and having a rather low deployment target. Most likely this is because the Icelandic government has just restarted investing in zero-emission vehicles (IPHE, 2016a). This case could reveal why the government decided to provide many different incentives and how these could help increase FCEV deployment.

Four other cases were **Germany**, **Japan**, **United Kingdom** and **United States.** All four have set deployment goals and provide both supply and demand-side incentives. One difference is the size of the car industry, with UK and US on the average while the other two are far above the average size. Another is the capitalism type where Germany and Japan belong to different types as compared to the UK and US. There are also differences when looking at the demand-side incentives. While Germany seems to focus only on tax incentives, the UK, US and Japan also provide a purchase subsidy. Furthermore, the US also provides non-financial incentives like usage of additional lanes while

Germany, Japan and UK do not (NCSL, 2015). These cases could reveal why countries with a big car industry invest heavily in the deployment of FCEVs. Also, these cases could reveal why each country chooses different types of demand-side incentives and whether and how the capitalism type influences these choices.

In the case of the United States, there was more specifically looked at California as this state is responsible for the high FCEV deployment. In the entire US, 1295 FCEVs are deployed of which 1259 are in California (HARC, 2016a). Furthermore, a number of studies have used California as a case to analyse different zero-emission vehicles policies between countries. For example, an ICCT (2015) study has compared Germany and California showing that this approach is appropriate and that California can be compared with other countries.

An overview of the gathered data on the selected countries can be found in table 2. When the cases where selected, interviewees were approached via e-mail. To increase the response rate, members were contacted, if possible, through the IPHE network while also referencing the point of the research.

Table 2. Cases for in-depth analysis (SS = supply-side incentive, DS = demand-side incentive)

Country	FCEVs	HRSs	Size of car industry	Capitalism type	Deployment goal (2020)	Incentives
Belgium	0,000490%	3	4,0%	Managed	1.000	DS
California	0,004279%	31	2,6% (entire US)	Market	18.465	SS and DS
Canada	0,000140%	2	5,3%	Market	no target	SS
Germany	0,000262%	37	6,4%	Managed	150.000	SS and DS
Iceland	0	0	no data	Managed	>80	DS
Japan	0,000575%	84	9,1%	State	100.000	SS and DS
the Netherlands	0,000500%	2	1,0%	Managed	2.000	DS
Norway	0,001088%	6	0,0%	Managed	no target	SS and DS
United Kingdom	0,000159%	13	2,3%	Market	15.000	SS and DS

3.4 Data analysis

For the variables varieties of capitalism and economic interest, a quantitative approach was used. Since the dependent variable of RD&D subsidies was not normally distributed, a non-parametric analysis was done. For the variable varieties of capitalism, Mann-Whitney U tests were used to identify whether the different capitalisms types influence the subsidies on RD&D. For the economic interest variable, a Spearman correlation was used to assess whether the size of the car industry influences the height of RD&D subsidies.

Since the interview data was qualitative, a qualitative content analysis method was used to analyse the data (Berg and Lune, 2011; Flick, 2009). Here, interviews were transcribed and coded using NVivo. This coding process followed three different steps. The first step was open coding where recurring phenomena were broken down into concepts. The second step was axial coding where these identified concepts were divided into categories. The last step was selective coding where the identified concepts were related back to the theoretical concepts derived from the independent variables. Using these three steps ensured that no potentially relevant data was lost and allowed for the identification of other theoretical concepts not previously identified. This approach thus supported both the deductive and inductive aspects of this research.

3.5 Research quality indicators

The literature generally distinguishes four research quality indicators which are about internal and external reliability and validity. Several measures were taken to ensure this research adheres to these quality indicators and is replicable, reliable and valid. *Internal reliability* was increased by checking inter-coder reliability by having two fellow students check the coding. The Krippendorff's alpha is

0,844, indicating that the two coders have interpreted the data similarly and inter-coder reliability is ensured (Krippendorff, 2004). Because of the qualitative nature of this research, *external reliability* is rather low (LeCompte and Goetz, 1982). By providing insight into the employed data collection and analysis techniques and by providing the interview guide, external reliability is increased. *Interval validity* is rather high because of the qualitative nature of this research and because of the extensive literature review done before doing the interviews. Quantitative data on all countries was collected and used to select cases for further research. Furthermore, between six to ten countries were selected. These measures ensured that the sample is a good representation of the population and thus increases *external validity*. The population however only includes countries active in developing and/or introducing FCEVs and thus might only provide a good representation of IPHE members. Applying the results of this research to countries not active in FCEVs is thus difficult and hampers external validity.

4. Results

The first part of the results section discusses the quantitative analysis of this research with some additional clarifying quotes. First, an overview of the data gathered on the entire population of countries assessed in this research is provided. Data on the entire population is then used to assess the influence of the different varieties of capitalism distinctions as well as the size of the car industry on the RD&D subsidies provided by governments. The second part of the results section discusses the qualitative, in-depth analysis of nine countries which were selected on the basis of the data gathered on the entire population (see section 3.3). This in-depth analysis assessed the influence of policy goals and rationales, political influence strategies, previously implemented policies, dispersal of power and national resources on the choices for different policy instruments.

4.1 Quantitative analysis

4.1.1 Descriptive statistics

From the gathered data, it becomes apparent that there are clear differences between countries. The entire population consists of 32 countries. The total number of FCEVs in the population is 2486 vehicles spread across 23 countries, 9 countries have no FCEVs or no data was available. The average percentage of FCEVs as compared to entire vehicle fleet is 0,0033% while the highest deployment percentage is in California (0,004279%). The average number of HRSs is 7 while the most are in Japan (84) and Germany (37). The highest FCEV to HRS ratio is California (40:1) followed by the Netherlands (20:1). Among the lowest is Japan (5:1) Germany (3:1). The average car industry size is 2,9% of the national GDP while the highest is 9,1% (Japan) followed by 6,4% (Germany). 5 countries do not have any incentives for FCEVs, 3 countries have only supply-side incentives, 10 countries have only demand-side incentives and 15 countries have both. 15 countries have set explicit FCEV deployment targets while 4 countries have stated explicitly that no targets are set. Lastly, the population includes 6 countries of the market capitalism type, 11 of the managed capitalism type and 8 of the state capitalism type. 7 countries belong to other capitalism types, either East-Central European (5 countries) or Latin American (2 countries). Table 3 below provides an overview of the gathered data on the countries. Figure 2 shows the countries with at least one FCEV on the road as percentage of total fleet. Deployment numbers as compared to total fleet are high for California, Denmark and Norway. California, Germany and Japan have set ambitious deployment targets for 2020 as well as large numbers of HRSs. Furthermore, the FCEV to HRS ratio shows that California and the Netherlands might focus more on deploying vehicles while Japan and Germany focus more on putting in the infrastructure.

Appendix C shows the RD&D subsidies provided in the category Hydrogen and Fuel Cells over the years 2010-2014 as gathered by the IEA. Unfortunately, for some countries, data on the RD&D subsidies is not provided by the IEA probably because of unavailability of data. Furthermore, data on the sales and infrastructure incentives is not gathered by the IEA and are not included here. Both these points pose a drawback to this research and are further discussed in section 5. The average RD&D subsidies provided is 102,22 million USD while the total amount spent between 2010 and 2014 is nearly 3 billion USD. Figure 3 shows the RD&D subsidies provided as percentage of GDP and makes comparison between countries easier. What this shows is that Denmark, Norway and Japan seem to spend the most. These countries thus could be seen as being highly active in hydrogen and fuel cells RD&D or at least the government seems to provide strong support for them. This data is further used in the next paragraphs to specifically assess the influence of the varieties of capitalism and economic interest variables.

Table 3. Gathered data (SS = supply-side incentive, DS = demand-side incentive).

Country	FCEVs	HRSs	Size of car industry	Capitalism type	Deployment goal (2020)	Incentives
Australia	0,000024%	1	1,9%	Market	no target	none
Austria	0,000506%	4	3,6%	Managed	no target	SS and DS
Belgium	0,000490%	3	4,0%	Managed	1.000	DS
California	0,004279%	31	2,6% (entire US)	Market	18.465	SS and DS
Canada	0,000140%	2	5,3%	Market	no target	SS
Czech Republic	0,000018%	1	3,8%	East-Central European	no data	SS and DS
Denmark	0,002660%	11	0,5%	Managed	100.000 (2025)	SS and DS
Finland	0,000027%	2	0,5%	Managed	4.000 (2025)	SS and DS
France	0,000450%	12	4,6%	State	1.000	SS and DS
Germany	0,000262%	37	6,4%	Managed	150.000	SS and DS
Greece	0,000062%	0	0,1%	State	no data	DS
Hungary	0	0	3,5%	East-Central European	no data	none
Iceland	0	0	no data	Managed	>80	DS
Ireland	0,000044%	0	no data	Market	0	SS and DS
Italy	0,000057%	2	2,7%	State	1.000	SS and DS
Japan	0,000575%	84	9,1%	State	100.000	SS and DS
Korea	0,000164%	7	3,9%	State	9.000	SS and DS
Latvia	0	0	no data	East-Central European	no data	none
Luxembourg	0,000481%	0	no data	Managed	no data	DS
Mexico	no data	0	0,2%	Latin American	no data	SS and DS
the Netherlands	0,000500%	2	1,0%	Managed	2.000	DS
New Zealand	0	0	0,0%	Market	no data	none
Norway	0,001088%	6	0,0%	Managed	no target	SS and DS
Poland	0	0	1,8%	East-Central European	no data	SS
Portugal	no data	0	1,6%	State	no data	DS
Slovak Republic	no data	0	6,0%	East-Central European	no data	DS
Slovenia	0,000171%	1	2,6%	East-Central European	1% of total fleet	DS
Spain	0,000144%	2	5,1%	State	no data	DS
Sweden	0,000444%	4	5,9%	Managed	8.000	SS
Switzerland	0,000373%	4	0,9%	Managed	no data	SS and DS
Turkey	no data	1	2,0%	State	no data	DS
United Kingdom	0,000159%	13	2,3%	Market	15.000	SS and DS

Sources: EAFO, HARC, OCIA, NetInform, World Bank, Schmidt (2002 & 2003), internet searches

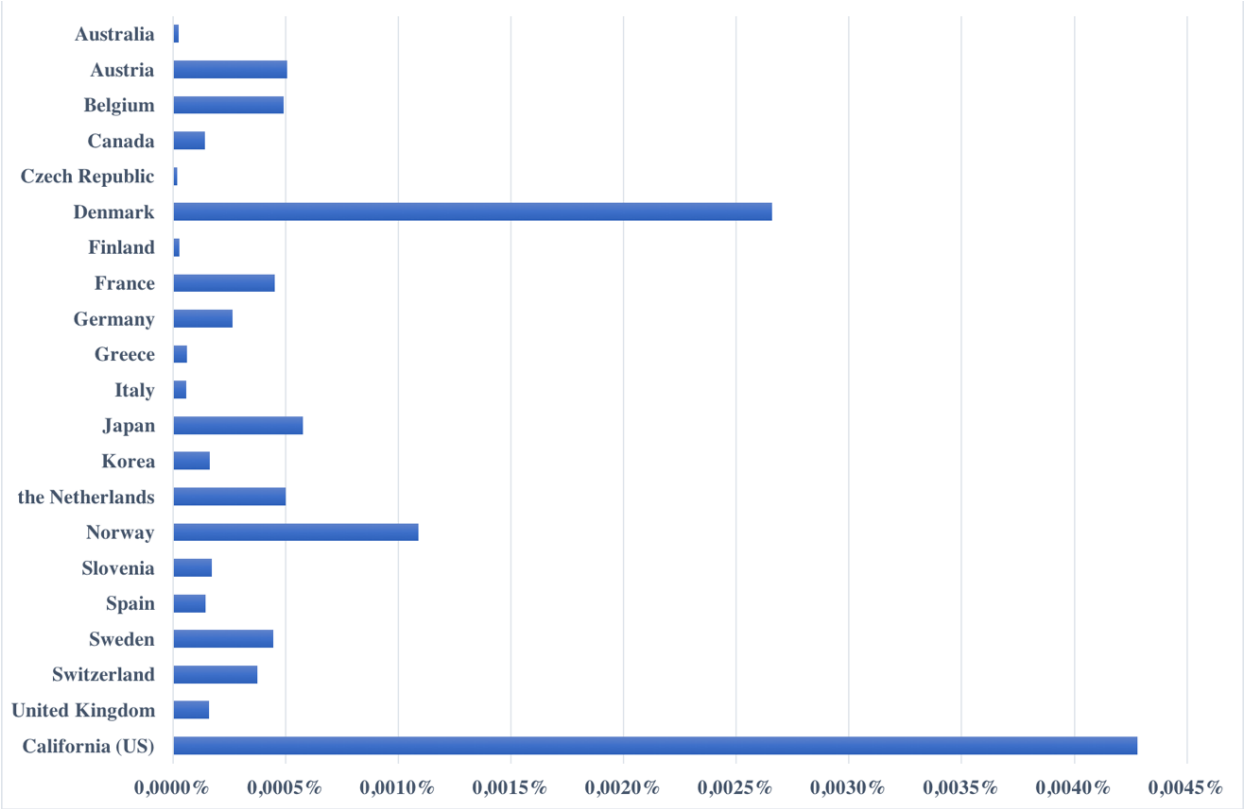

Figure 2. Number of FCEVs as percentage of total vehicle fleet. Sources: EAFO, HARC, OCIA

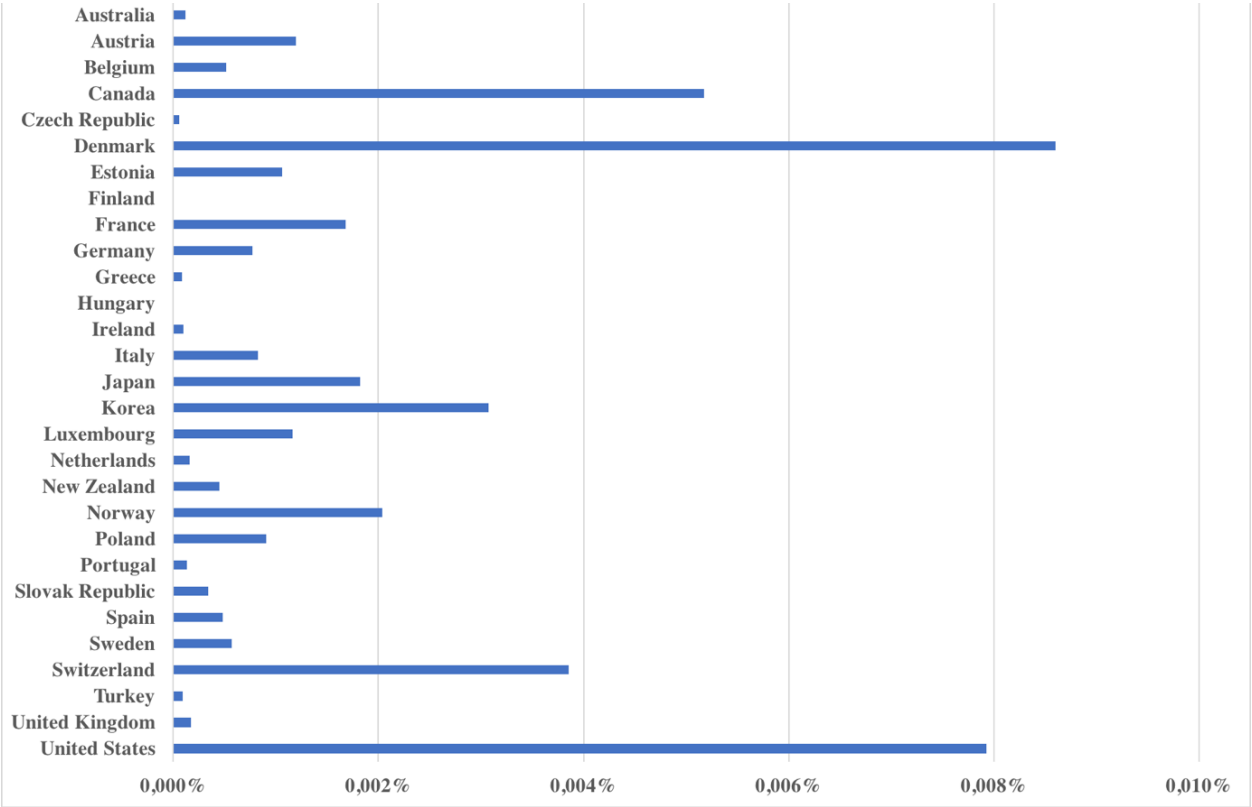

Figure 3. RD&D subsidies for Hydrogen and Fuel Cells in 2010-2014 as percentage of GDP. Sources: IEA, World Bank

4.1.2 Varieties of capitalism

Table 5 shows the results of the Mann-Whitney U comparison between the different varieties of capitalism types and RD&D subsidies. What becomes apparent is that there are no significant differences between these distinction and RD&D subsidies. It was expected that stronger intervention on economic actors and activities, and thus state capitalism, would lead to higher subsidies. While the results are not significant, they show the direct opposite where market capitalism countries seem to spent the most on RD&D subsidies. An example of this is the conservative Business Minister Michael Fallon of the UK stating *"we already have a strong automotive sector and must ensure it stays that way"* (DBIS, 2013) thus justifying the support for the automotive sector. This shows that countries categorized as market capitalism might state they want to let the market operate autonomously and let economic actors be free, but at the same time provide high subsidies to support that same industry. However, since the results are not significant, it becomes clear that the varieties of capitalism typology cannot sufficiently explain the presence and height of industrial RD&D subsidies or at least not in the way expected according to the scientific literature.

Table 5. Mann-Whitney U comparison between varieties of capitalism and RD&D subsidies

Dependent variables	N	RD&D subsidies	
		Mean Ranks	U and z value
Market	5	16,60	37
others	21	12,76	-1,009 (p = 0,34)
Managed	9	13,72	74,5
others	17	13,38	-0,108 (p = 0,916)
State	8	14,63	63
others	18	13,00	-0,500 (p = 0,644)
East-Central European	4	6,88	17,5
others	22	14,70	-1,884 (p =0,058)

4.1.3 Economic interest

Calculating the correlation between the RD&D subsidies and the turnover of the car industry using a Spearman test showed a strong positive relation (0,650) and is significant at the 0,001 level. This means that if the turnover of the car industry in a country is higher, the height of RD&D subsidies is also higher. This supports the statement that governments tend to support their car industry by providing RD&D subsidies. This also becomes apparent from the countries with a large automotive industry (turnover car industry more than 1% of GDP) selected for in-depth analysis in section 4.2. For example, Germany states that *"the measures provided ... will act as a catalyst to enable the German motor-vehicle manufacturing and parts supply industry ... to build up its own research and development activities and gain technological and market leadership in electromobility"* (BMVI, 2009, p.4). Similarly, Japan states that *"the government aims to capture 50 to 70% of next-generation vehicles to total new car sales by 2030, to this end, the government will take measures such as creating initial demand, supporting R&D to improve performance, developing infrastructure, and so on"* (METI, 2014, p.2). This shows that there is a clear relation between RD&D subsidies provided by governments and the size of the car industry. This thus supports the statement that a bigger car industry leads to higher subsidies stimulating the production and development of hydrogen and fuel cell technologies potentially useful for FCEVs. An additional Spearman test showed there is also a strong positive correlation (0,604) between the number of FCEVs and turnover of the car industry, significant at the 0,005 level. This might show that, next to providing RD&D subsidies, countries with a higher car industry turnover could also be more active in deploying FCEVs. Concluding, a higher turnover of the car industry leads to more subsidies into research and development as well as higher deployment number of FCEVs.

4.2 In-depth, qualitative analysis

Table 6 shows the supply and demand-side incentives that apply to FCEVs in the countries selected for in-depth analysis. These countries were selected on the basis of data gathered on the entire population on which a discussion can be found in section 3.3. The RD&D subsidies data was previously gathered for the case selection and comes from table 3. The demand-side incentives were gathered for the selected countries, an overview of the specific incentives can be found in appendix D. For both tax incentives and non-financial incentives, either a + or ++ is shown. In the case of tax incentives, one + means that there is only one tax incentive while ++ means there are multiple. In the case of non-financial incentives, one + means only some regions or cities provide these incentives while ++ means that these incentives are provided at the national level.

Table 6. Supply and demand-side incentives

Country	RD&D subsidies	Infrastructure incentives	Consumer incentives		
			Tax incentives	Purchase subsidy	Non-financial incentives
Belgium	no	no	yes (+)	no	yes (+)
California	yes	yes	no	yes	yes (++)
Canada	yes	yes	no	no	yes (+)
Germany	yes	yes	yes (+)	yes	yes (+)
Iceland	no	no	yes (++)	no	yes (+)
Japan	yes	yes	yes (++)	yes	yes (+)
the Netherlands	no	no	yes (++)	no	no
Norway	yes	no	yes (++)	no	yes (++)
United Kingdom	yes	yes	no	yes	yes (+)

4.2.1 Policy goals

From the policy documents, it becomes clear that the policy goals of FCEV policies for the nine selected countries can be subdivided into environmental, economic and energy goals. Table 7 provides an overview of the goals explicitly mentioned in the policy documents and which goals apply to which countries.

The **environmental goals** can be divided into two broad categories. The first is explicitly mentioned by all countries except for Norway and relates to reducing CO2 or GHG emissions. For example, The Canadian Hydrogen and Fuel Cell Association (CHFCA) states that *"hydrogen and fuel cells are important clean energy technologies that help Canada achieve its greenhouse gas and pollution reduction goals"* (CHFCA, 2010, p.3). The second category is explicitly mentioned by Belgium, California, Canada, Germany and the UK and is about improving local air quality. For example, Belgium states that electric vehicles can *"solve acute problems like improving air quality, not just in busy city centres but also everywhere else"* (Belgium Federal Government, 2017, p.116, translated from Dutch).

The **economic goals** can be divided into two broad categories. The first is explicitly mentioned by Belgium, California, Canada and Germany and relates to strengthening or creating opportunities for car manufacturers. For example, Germany states that *"strategic alliances in power train electrification with the traditionally well-placed German parts suppliers could provide substantial innovatory impetus to the German motor-vehicle manufacturing industry"* (BMVI, 2009, p.8). The second is explicitly mentioned by all countries except for Germany and Japan and relates strengthening or creating opportunities for the domestic industry. For example, UK H2 mobility states that *"hydrogen as a technology option that could lead to opportunities in employment creation across the value chain (from vehicle manufacture, development of new components, fuel production, distribution and supply, etc.) and thereby bring significant economic benefit to the UK"* (UK H2 Mobility, 2013, p.3).

The **energy goals** can be divided into two broad categories. The first is explicitly mentioned by Belgium, Canada, Germany, the Netherlands and Norway and relates to using hydrogen for the storage of renewable energy. For example, the CHFCA states *"that electricity can be stored in the form of hydrogen and, using fuel cells, can be turned back into electricity at the time it is needed most*" (CHFCA, 2010, p.3). Similarly, the Norwegian Hydrogen Forum states that the hydrogen infrastructure might play a crucial role in grid balancing and energy buffering because 96% of the electricity produced comes from renewables (Norwegian Hydrogen Forum, 2016, p.6). The second is explicitly mentioned by all countries except for California, Canada and Norway and relates to energy security and independence. For example, Japan states that *"utilizing hydrogen manufactured from renewable energy in Japan may also increase the energy self-sufficiency rate in the future"* (METI, 2014b, p.2). Another example is given by an interviewee from Iceland who states *"we are looking at all options which will reduce the use of fossil fuels and use domestic resources"* (interviewee 11).

Overall, looking at the used policy instruments and goals, it becomes clear that countries focussing less on environmental goals seem to have more consumer tax incentives. With the exception of Japan, these countries also seem to focus less on RD&D and infrastructure incentives.

Table 7. Explicit policy goals per country

	Environmental goals		Economic goals		Energy goals	
	Reducing CO2 or GHG emissions	Improve local air quality	Strengthening or creating opportunities for car manufacturers	Strengthening or creating opportunities for domestic industry	Use hydrogen for storage renewable energy	Energy security/ independence
Belgium	x	x	x	x		x
California	x	x	x			
Canada	x	x	x	x	x	
Germany	x	x	x		x	x
Iceland	x			x		x
Japan	x			x		x
the Netherlands	x			x	x	x
Norway				x	x	
United Kingdom	x	x		x		x

4.2.2 Policy rationale

From the interviews and policy documents it becomes clear that the three identified failures are applicable to a number of countries and, in some instances, are important reasons for setting up and using specific policy instruments. An overview of which failures have been used to rationalize policy intervention by the interviewees in their specific country can be found in table 8.

The **market failure** argument is deemed a reason for the incentives by all countries. For example, an interviewee from California states *"we know industry does not prioritize it the same way, so from the regulation that created the ZEV mandate for the vehicle manufactures to all the supporting mechanisms that went with it, it definitely was an intervention to put this as a priority within the state of California"* (interviewee 3). In all instances, the interviewees state that the incentives are in place to compensate the consumer for the price difference of the more expensive FCEVs. For example, an interviewee from Canada states *"those incentives are in place to cover the difference between the cost of a regulation ICE and the cleaner version of it, be it an EV or FCEV"* (interviewee 5). Similarly, an interviewee from UK states that *"the difference in cost between a petrol or diesel vehicle and an ultra-low emission vehicle can be significant and the need for market intervention remains if we are to support a sustainable and growing mass market"* (OLEV, 2014, p.8). For this reason, different policy instruments are used in order to compensate for this price difference. For example, an interviewee from

Norway states they use a tax exemption because *"we have such high taxes on cars. We are talking half the price of the cars"* relating the chosen policy instrument to the current taxation scheme and thus previously implemented policies. An interviewee from British Colombia, Canada states they chose a purchase subsidy because *"the way people purchase vehicles is emotional and people sort of see an instant discount and can understand it and plan with that"* (interviewee 6). This shows the perception of the user, in this case the one receiving the subsidy, is an important reason for implementing a specific demand-side incentive. An interviewee from Iceland states that they chose tax exemptions rather than a purchase subsidy because *"it's a simpler approach because otherwise people would pay the government and then repay a certain amount of money which is two things at the same time. This is a relatively simple execution of an incentive program"* (interviewee 11). This shows that the simplicity of the instrument is an important indicator for why there was chosen for this instrument. Germany takes a slightly different approach and states *"the promotion of research and development is a prerequisite for achieving further cost reductions … for the vehicles"* (BMVI, 2013, p.74). One could thus argue that, in the case of Germany, funding of R&D, which indirectly lowers the price of FCEVs, is used rather than providing consumers with a purchase subsidy or tax exemption.

It also becomes apparent that the **structural systems failure** argument is a reason for setting up policies in the case of Belgium, California, Germany, Japan, the Netherlands and Norway. For example, an interviewee from the Netherlands states *"we are really searching, stimulating and supporting that cooperation"* (interviewee 8). Similarly, Japan states *"academia, government and industry will collaborate to proactively engage in measures for utilizing hydrogen"* (METI, 2014b, p.2). What also becomes apparent is that in the case of California, Canada and the UK, public-private partnerships are setup to increase and improve cooperation between different actors. For example, an interviewee from California states *"improving cooperation and minimizing risk taken across the board, I think that was why the [California Fuel Cell Partnership (CAFCP)] was developed"* (interviewee 3). Similarly, Canada's CHFCA and UKs UK H2 Mobility are also setup to improve this cooperation.

Lastly, the **transformational systems failure** argument is deemed applicable by all countries except for Belgium. For example, an interviewee from Iceland states the financial incentives in the form of tax breaks are done *"so that we can start the transformation to a fossil fuel based society into a renewable based society"* (interviewee 11). Similarly, an interviewee from California states "*if we are going to transform the system, we need to have a set of mechanisms and triggers that facilitate the transition across all of the players because there is going to be many different things that need to be supported"* (interviewee 3). One could argue that this supporting all aspects argument can help explain why California choose consumer incentives in the form of purchase subsidies and non-financial incentives as well as infrastructure incentives. Furthermore, an interviewee from California states that such an approach requires different incentives across time where *"the goal really is to get [the transformation] started, then let government withdraw from the market and let it become a true market place"* (interviewee 3). Lastly, it becomes apparent that the market failure and transformational system failure argument in some instances is deemed as relating to the same thing. For example, an interviewee from Norway states that "*they are kind of two sides of the same coin. The market failure focusses on the economy, the benefit of the investor. The other one, the incumbent technologies but it is the same process"* (interviewee 4). What this shows is that these two types of failures might be distinguished analytically in the literature but might not actually be deemed different reasons for setting up policy instruments supporting FCEVs.

Table 8. Types of failures applicable to different countries.

	Market failure	Structural system failure	Transformational system failure
Belgium	x	x	
California	x	x	x
Canada	x		x
Germany	x	x	x
Iceland	x		x
Japan	x	x	x
the Netherlands	x	x	x
Norway	x	x	x
United Kingdom	x		x

4.2.5 Political influence strategy of car manufacturers

From the policy documents and interviews it becomes clear that each country has consultation with its industry regarding policies for FCEVs. As mentioned previously, Canada, California and the UK have also set up public-private partnerships for this purpose. Six of the nine countries included in this in-depth analysis have a car industry size of more than one percent and thus could be seen as being of importance for the domestic economy. This does not include Iceland, the Netherlands and Norway and these are therefore not included for analysis of this variable.

Belgium, Germany and the UK state their car industry has no opposition to the current instruments and might actually want more support from the government in the form of consumer incentives. In these instances, this stance could be interpreted as **progressive political influence strategy** as they want increased amounts of incentives. For example, an interviewee from Vlaanderen, Belgium states *"some stakeholders are proponents of increasing support measures for FCEVs because the cost price is higher as compared with other technologies"* (interviewee 10, translated from Dutch). This also applies to Germany where the government before 2016 did not provide a purchase subsidy which *"flies in the face of German carmakers, who had lobbied hard for such support"* (DW, 2010).

California and Canada state their car industry is supportive of the current, financial support instruments but is less supportive of instruments regulating their activities. Their approach could be deemed a **supportive political influence strategy** since they deem, at least some of, the incentives as advantageous for their activities. An interviewee from Canada states that their manufacturers *"want to ensure that the appropriate infrastructure is in place in Canada to support the deployment of their vehicles when those vehicles are available"* (interviewee 5). For this purpose, they have set up a proposal which they *"are circulating amongst governments and politicians to encourage a more rapid deployment of infrastructure"* (interviewee 5). What also becomes apparent is that the manufactures oppose regulatory instruments. Both California and Quebec, Canada have already implemented a ZEV mandate where an interviewee from California states *"when they proposed the ZEV regulation it was fought in lawsuits and debates and they had to work it out through a bit of combative style to find something that everyone can work with"* (interviewee 3). Similarly, an interviewee of British Colombia, Canada states it is thinking of implementing a ZEV mandate and that they *"will sort of have to see how the interaction goes but the auto manufacturers are very much not supportive of regulation. They want the market to show the winning technology and the speed at which consumers will adopt these vehicles"* (interviewee 6).

Overall, what becomes clear is that in countries with a car industry, the car manufacturers take on both a supportive as well as progressive political influence strategies but do not respond positively to regulation of their activities in the form of a ZEV mandate. Looking back at the policy instruments used, all countries with a car industry, except for Belgium, seem to use both RD&D and infrastructure incentives. All countries also use consumer incentives but a difference between the supportive and progressive strategy and which specific consumer incentives are used was not identified.

4.2.6 Previously implemented policies

From the interviews and policy documents it becomes clear that California, Canada and the Netherlands deem a low carbon fuel standard an important **complementary** policy instrument. For example, an interviewee from Canada states *"low carbon fuel standards will help to ensure that people start investing in hydrogen refuelling stations, otherwise they are going to get taxed for it"* (interviewee 5). An interviewee from California however also mentions a potential drawback of such a standard stating *"you don't keep making gasoline cleaner and eventually it becomes hydrogen or electricity"* (interviewee 3) showing that the choice for such a policy instrument requires constant tweaking.

Canada, Iceland and Norway mention the importance of a carbon tax which can be seen as another complementary policy instrument. For example, an interviewee from Iceland states *"increasing taxes on CO2, increases taxes on fuels to actually help the introduction of zero emission vehicles into the fleet"* (interviewee 11). An additional benefit of a carbon tax is mentioned by an interviewee from Canada stating *"those taxes, which generate a lot of money, could be used to help pay for infrastructure development"* (interviewee 5). An interviewee from the UK deems taxing of existing ICE vehicles difficult stating *"politically that will be very difficult. The low emission market is still very small in comparison, so you will be penalizing a large percentage of the population"* (interviewee 12) and thus have not implemented such a taxation. The Netherlands also states a potential drawback which *"has led to a stacking of fiscal measures where the logic in and between different taxes is not always clear. This has in part led to a system that is perceived as being complex"* (Ministerie van Financiën, 2011, p.6, translated from Dutch). Therefore, the Netherlands have introduced a new taxation scheme by introducing the so called Autobrief II which simplified the taxation of lease vehicles based on their pollution.

An important complementary policy instrument is a ZEV mandate. This forces car manufactures to produce a certain percentage of ZEVs as part of their total production. Canada, California and the Netherlands state the importance of such an instrument. For example, an interviewee from the Netherlands states *"we need to move towards regulations stating numbers of zero emission vehicles as in California. It is extremely effective if you can introduce such a policy"* (interviewee 7, translated from Dutch).

Important to mention is that the three discussed complementary policy instruments have not been implemented by all mentioned countries. California is the only one who introduced a low carbon fuel standard and a ZEV mandate while Canada and Norway are the only ones who introduced a carbon tax. In the cases where no such instruments are introduced, the policies are thus not previously implemented but rather policies that are deemed useful and complementary to FCEV policies. This poses a drawback when talking about previously implemented policies and will be discussed in section 5.3.

Some **incompatible** policy instruments are also identified. Belgium and Germany both have incentives for diesel in place. For example, an interviewee from Germany states *"that the incentives on diesel fuel are hindering alternative fuels in general"* (interviewee 2). This has led to high number of diesel vehicles in these countries. Furthermore, these incentives for diesel keep the fuel price artificially low and could increase the attractiveness of buying a diesel car rather than a ZEV which thus could hamper the adoption of ZEVs.

Related to the previously implemented policies is whether policies in place are **technology neutral** or support a specific technology. All countries except for Japan state the importance of being technology neutral. For example, an interviewee from California states they are *"very careful and try not to pick winners or losers because they have learned historically that it may not be the best suited to make those choices of the market"* (interviewee 3). An interviewee from Norway states they now support all technologies equally but will most likely lower the generous support for BEVs because of large deployment numbers, while at the same time maintaining high support for FCEVs because not that many of these vehicles are yet deployed. (interviewee 4). From this statement, one could argue that once

technologies are in different deployment stages, maintaining a technology neutral approach might be more difficult as different technologies require different amounts of support. It is however also possible that because of this difference in support, each technology gets an equal chance on the market which can also be deemed technology neutral by policy makers. What this shows is that technology neutrality is interpreted differently by policy makers and the term might require further specification.

Overall, what becomes clear is that low carbon fuel standards, carbon taxes and a ZEV mandate are three policy instruments that could help the deployment of FCEVs. Diesel incentives could hamper the effectiveness of financial, consumer-orientated FCEV incentives as diesel vehicles might be cheaper and thus more attractive to consumers. Lastly, technology neutrality in policies is deemed important but the term might need further specification as to what different choices are being made for new technologies during different deployment stages.

4.2.7 Dispersal of power

From the interviews and policy documents it becomes clear that for the deployment of FCEVs and refuelling infrastructure, national governments work closely together with regional governments. Furthermore, it becomes apparent that Belgium, California and Canada have a strong regional focus (e.g. state, provincial) while Germany, Iceland, Japan, the Netherlands, Norway and the UK tend to have a more national approach. Each country also mentions the importance of working together with regions and cities for achieving deployment goals for FCEVs.

It becomes apparent that the more general RD&D subsidies are usually provided at the national level. Furthermore, countries with a strong regional focus tend to allow their regions to define specific consumer incentives. Incentives like free parking and HOV lane access are usually decided upon at the local or city level. For example, an interviewee from California states *"federal government, for example Department of Energy, continues to focus more on the R&D side and less on the commercial deployment side"* (interviewee 3). An interviewee from the Netherlands also states *"we are currently formulating financial incentives and are looking at how we can make sure it supports all kinds of regional initiatives"* (interviewee 8, translated from Dutch) showing the importance of regional initiatives. Lastly, about who gets to decide about the non-financial incentives, an interviewee from Norway states *"it used to be nation-wide, but formally it will be regional by the end of this year"* (interviewee 4) showing that some countries choose to let regions be responsible for the implementation of policies with regards to FCEVs. This is also applicable to Canada, who themselves have not yet formulated an implementation plan with regards to FCEVs where an interviewee states *"provinces and territories have the flexibility to design their own policies and programs"* and *"our preference is to give them guidance or let them lead by example"* (interviewee 5).

However, this **vertical dispersal of power** between different government levels sometimes leads to difficult situations. For example, Belgium states that the "*mix of governmental authorities makes a clear uniform support scheme for sustainable transport on the overall Belgian-level complicated*" (H2 Mobility Belgium, 2015, p.16) supporting the statement that if power is dispersed between different levels of government, the formulation of policies, in this case a support scheme, is more difficult. In some instances, regions want to be allowed to make their own decisions. For example, an interviewee from Germany states *"the cities are asking for frameworks within which they could act. They don't want to be over-ruled but they want to get the instruments and to have a clear framework how to act"* (interviewee 2). While California still has to deal with legislation at the national level, they *"have been given a waiver for decades, enabling them to be more aggressive than the federal government wants to be"* and thus on a regional level are allowed to implement more ambitious policies.

What also becomes apparent is that no countries except for the Netherlands state there are issues with **horizontal dispersal of power** and there is thus less than ideal coordination across different

ministries. This dispersal of power is mainly between the ministry of Environment and that of Finance where the first ministry states *"purchase subsidies did work but turned out to be so expensive that the Ministry of Finance said, we are not continuing with this and this financial stimulation was toned down"* (interviewee 7, translated from Dutch). They state that *"the total costs and benefits are not taken into account, there is only looked at cost-effectiveness"* by the ministry of Finance and that this *"is just too little, you need to look at it from a broader perspective and think of achieving those general policy goals together"* (interviewee 7, translated from Dutch). The ministry of Environment is trying to solve this by *"trying to substantiate the benefits in financial terms for EV and FCEVs so that we can provide a better argument for why that fiscal support from the federal government is necessary"* (interviewee 7, translated from Dutch). What this shows is that different ministries can have different views on why a specific policy instrument should be used and also look differently at the costs and benefits of such an instrument. An interviewee from Germany however states that *"everybody has its role to play. If you wouldn't have different ministries, you would have different departments. So, you have different interests and the art of making policy is to find a balance between the different interests or to value the different interests"* (interviewee 2). What this could show is that some horizontal dispersal of power is almost always present and is just a reality every policy makers has to deal with.

Overall, it becomes clear that general, not technology specific, RD&D subsidies are provided at the national level while specific consumer incentives are implemented on other governmental levels such as regional or local. Furthermore, both vertical as well as horizontal dispersal of power can lead to complex situations that might lead to difficulties when choosing policy instruments.

4.2.8 National resources

From the interviews and policy documents it becomes clear that mainly the natural resources and industrial activities in countries are important factors and could help explain why FCEVs play an important role in the ZEV mix.

Abundance of **natural resources** that can be used to generate electricity seems to be an important driver. This seems to apply mainly to Canada, Norway and Iceland who use hydro and/or geothermal power to generate most of their electricity. These countries state that there is no preference whether this electricity is used to charge BEVs or generate hydrogen for use as fuel in FCEVs. For example, an interviewee from Iceland states *"the government doesn't care how they use the electricity which we produce from renewable sources"* stating it can be used for both BEVs and for hydrogen for FCEVs. (interviewee 11). This abundance leads to two important points. The first is that because it is produced domestically, electricity is cheap and thus might be an important incentive for consumers to purchase an electric vehicle. For example, an interviewee from British Colombia, Canada states *"there is a massive economic argument for people to adopt electric vehicles due to the cost savings they are going to realize for that"* (interviewee 5). Furthermore, this leads to increased energy security and less energy importation and thus cost savings for the government. For example, an interviewee from Iceland states *"if you get rid of fossil fuel import, it saves a lot of foreign capital because we have no fossil fuel resources in Iceland, we have a lot of domestic energy"* (interviewee 11). The second point is that, because most of this energy comes from renewables, this sector generates less emissions. Since these countries have also committed to reducing their total CO2 and GHG emissions, reduction of these emissions in the transportation sector becomes more important. For example, an interviewee from Norway states *"we don't have so many places to cut because our energy system is hydropower. So, we will have to do a lot in transport and agriculture"* (interviewee 4). What this shows is that the abundance of natural resources leads to an important economic as well as environmental argument on why specific support for FCEVs is necessary.

An important **industrial activity** seems to be the presence of industries that use hydrogen for production activities or have hydrogen left over from other processes. This seems to apply the most to Belgium, California, Canada and the Netherlands. For example, Belgium states *"the port of Antwerp is one of Europe's biggest areas for the production of hydrogen (coming from natural gas as well as being a by-product from chemical industry)"* (H2 Mobility Belgium, 2015, p.14). What however also becomes apparent is that this leftover hydrogen cannot remain a reliable source for the fuel once it is required in bigger quantities. For example, an interviewee from California states *"as we get more hydrogen demand for the vehicles, we know that we need to start producing more hydrogen specifically for transportation, specifically renewable"* (interviewee 3) showing that the presence of such activities might only be of importance in the early stages of FCEV deployment when not much hydrogen fuel is needed.

Overall, what becomes clear is that both natural resources and industrial activities are important factors that help explain why some countries focus on stimulating the development, production and/or deployment of FCEVs. Furthermore, one could argue that these two factors mainly influence the choice for infrastructural policy instruments since hydrogen is already available and can be used in refuelling stations.

5. Discussion

5.1 Theoretical implications

This research shows that in industrialized countries over the past five years, there are important differences in the type and amount of policy instruments chosen for fuel cell electric vehicles. The results indicate that the proposed conceptual model contains some variables that can be deemed good indicators for why specific policy instruments are chosen. However, the quantitative analysis revealed some unexpected findings relating to the identification of no causal relationship between the RD&D subsidies and varieties of capitalism distinctions as well as the deployment of FCEVs being higher in countries with a large car industry. The qualitative analysis also revealed some unexpected findings relating to how policy makers understand the market and transformational system failures as well as technology neutrality concepts. This research helped create a better understanding of which factors influence policy instrument choice by showing that factors relating directly to the used policy instruments (policy goals and rationale) as well as more contextual factors such as economic interest and dispersal of power are of importance for how policy instruments are selected.

The quantitative analysis in this research shows there is a correlation between the turnover of the car industry and the height of the RD&D subsidies and that when the turnover of the car industry in a country is higher, the height of RD&D subsidies is also higher. This finding is in line with the **economic interest** concept from a previous study by Wesseling (2016). However, contrary to this study, it becomes apparent that countries with a higher car industry turnover also deployed more FCEVs. This could show that these countries might also focus on deployment more and have also set up policies for this purpose. The qualitative analysis part of this research includes six countries with a car industry turnover of more than one percent and they all provide consumers incentives. The presence of incentives in these car-manufacturing countries could be explained by the fact that their car manufacturers are more in favour of FCEVs rather than BEVs. This could be explained by this technology being closer to their current business model. This is in line with a study by Wesseling et al. (2014) who showed that incumbent car manufacturers applied for about 70% of the FCEV patents while new entrants are primarily responsible for BEV patents. More detailed research could uncover if when a technology is close to the business model of incumbent car manufactures this also leads to the presence of more consumer incentives, if other car industry countries also seem to use deployment incentives next to RD&D subsidies and whether the height of the consumer incentives in other countries also correlates with the turnover of the car industry.

Contrary to what was expected, no causal relationship between the **varieties of capitalism** distinctions and the provided RD&D subsidies for hydrogen and fuel cells is uncovered. One explanation for this could be that market capitalism countries might state they let the market function autonomously but at the same time use strong industrial policies to support their industry (Block, 2008; Lazonick, 2011). Another explanation could be that this distinction translates into choosing regulatory and soft instruments rather than economic policy instruments. Since this research primarily focussed on economic policy instruments, further research could determine whether the varieties of capitalism distinction leads to choosing for regulatory and soft policy instruments rather than economic instruments.

The qualitative analysis in this research shows that the identified factors in the theory are important indicators for assessing policy instrument choices. An important finding is that there is some ambiguity surrounding the term **technology neutrality**. The literature describes technology neutrality in policies as policies that do not choose a specific technology (Azar and Sandén, 2011). It however becomes clear that some policy makers deem setting up policy instruments supporting different technologies differently (i.e. more support for new technologies than established ones) so that they have an equal chance on the market place as a form of technology neutrality. In the scientific literature, this

is however not deemed technology neutrality but rather labelled as creating a level playing field where governments takes measures that indirectly help cleaner technologies compete (Kemp and Rotmans, 2004; Kern and Smith, 2008). The difference between the two concepts thus relates to whether specific technologies are chosen and how they are supported. Thus, while a technology neutral approach does not choose a specific technology and supports all possible options equally, a level playing field approach choses competing technologies and might support them differently to give them equal chances on the market place. This finding shows that policy makers might not be aware of important concepts for sustainability transitions identified by academics and could point to a mismatch of knowledge between policy making and academics. Further research could therefore uncover what causes this mismatch and how academics can help resolve this.

5.2 Policy implications

An important finding which has implications for policy and policy makers is that both the **policy goals**, which can relate to environmental, economic and energy goals, and the **abundance of national resources** are important reasons for why policies for FCEVs are set up. While such circumstances are most likely well known by policy makers within a country, other countries who want to formulate and implement similar policies should be aware of these differences. This is important because these contextual factors are important indicators for why some policy instruments introduced in one country are successful while less so in other countries. Therefore, when implementing policies based on the successes in other countries, policy makers should take into account the underlying policy goals by which the success is measured and the national resources that enabled this success, and see whether similar circumstances are present in their own countries.

Another important finding is that policy makers deem the **policy rationale** distinction of market and transformational system failure as the same thing. They think that this distinction pertains to helping new technologies and that the only difference is that either an economic or technological perspective is taken. While there is some merit to this argument, this is not entirely true because transformational system failure is not only about technologies but also about inducing transformative change which requires taking a broader scope and long-term perspective (Weber and Rohracher, 2012). Inducing transformative change requires not only economic instruments directed at financially compensating actors to solve market failures but also regulatory and soft instruments to regulate and coordinate this change across different actors. Of importance are for example *"anticipating and learning about user needs"* and *"regulation or standards to guide and consolidate the direction of change"* (Weber and Rohracher, 2012, p.1045). Thus, it might be of importance for policy makers to be aware of newly developing rationales in the literature, reflect on how the introduced policies help this transformative change and look at how, next to economic policy instruments, a policy mix including regulatory and soft policy instruments can be setup to achieve this change.

Lastly, it also becomes apparent that **dispersion of power** between ministries tends to limit the possibility of formulating and implementing different policy instruments. The results showed that different ministries can have different views on why a specific policy instrument should be used and also look differently at the costs and benefits of such an instrument. In the case of the Netherlands, one ministry was having difficulties convincing another ministry of the total benefits of some policy instruments. One could argue that this leads to choosing a policy instrument deemed appropriate by all ministries rather than a policy instruments which has more potential benefits but where it is more difficult to substantiate these benefits. Therefore, policy makers could see in what way they can substantiate all the possible benefits of a policy instrument by for example seeing how environmental benefits translate into economic benefits.

5.3 Limitations

This research has some noteworthy limitations. The first relates to the type of incentives studied. In the quantitative analysis, only RD&D subsidies are used rather than also including spending on sales and infrastructure. This is because data on budgets for sales and infrastructure incentives was not always available or explicitly stated. Furthermore, searching policy documents for each country in the population would have been less reliable and time-consuming. This could lead to providing an incomplete overview of policy instruments used for FCEVs and can be especially problematic for countries who provide only sales and infrastructure rather than RD&D subsidies. Furthermore, RD&D subsidy data is up to 2014 and thus could lead to a skewed image not including countries who have just started or restarted their hydrogen and fuel cell RD&D activities. In the qualitative assessment, incentives other than economic supply and demand-side instruments were rarely mentioned by the interviewees. This could be because such incentives are deemed less important in the early stages of market introduction. Further research could uncover the role and importance of these regulatory and soft instruments in the policy mix for FCEVs.

Second, there are limitations with regards to research design and case selection. This applies to the more qualitative, in-depth analysis part of the research since a multiple-case study design was employed. While such an approach allows for gaining in-depth insight into why specific countries choose for specific policy instruments, these finding are difficult to generalize to the larger population and thus hampers external validity (Bryman, 2012). Nevertheless, as not many countries are very active with FCEVs specifically and the countries were carefully selected to represent the larger sample, studying these nine countries is still informative and provides context on the reasoning for choosing specific FCEV policy instruments.

Third, with regards to the **previously implemented policies**, the qualitative analysis revealed that it is sometimes difficult to see which policies are deemed relevant and influencing FCEV policies. Furthermore, the interview process revealed that some interviewees interpreted the questions about previously implemented policies as policies that *could* be introduced to help research, development and deployment of FCEVs rather than policies which *are* used at this moment. While both are limitations, this research provides a starting insight into which approaches are taken and how they could influence the formulation and implementation of specific FCEV policies. Further research could help set up an appropriate analytical framework with a well-defined scope in order to properly capture the influence of previously implemented policies.

Lastly, in the case of **political influence strategies,** it is important to mention that, next to the car manufactures, other stakeholder groups such as hydrogen producers can also influence policies through lobbying. The primary focus of this research was on car manufacturers since they play an important role because FCEV deployment is low and new FCEV models have yet to be introduced. Further research could uncover whether and how other stakeholders employ such strategies and how this influences the choices for FCEV policy instruments.

6. Conclusion

This research aimed at answering the research question: "*Which factors can help explain differences in policy instrument choice for fuel cell electric vehicles across industrialized countries between 2012 and 2016?*". For this purpose, a mixed-method approach was taken where a quantitative analysis of OECD countries together with qualitative, in-depth analysis of nine countries was done. A number of factors influence policy instrument choices which are the policy goals and underlying rationale, who is responsible for their formulation and implementation, what other policies have previously been implemented, what national resources a country has as well as the role of car manufacturers and their importance for the domestic economy. As shown in the policy implications, it is important for policy makers to be aware of differences in policy goals and national resources between countries as well as to take a broader scope and long-term perspective when formulating and implementing policies to induce transformative change. The most important contribution of this research is that it showed that choosing policy instruments is dependent on a multitude of factors and that understanding these factors can help future formulation and implementation of policies and help the transition towards new and sustainable technologies such as FCEVs.

References

ACEA, 2016. Overview of purchase and tax incentives for electric vehicles in the EU in 2016. Available at: https://www.acea.be/uploads/publications/Electric_vehicles_overview_2016.pdf. Last accessed: 3/7/2017.

Alkemade, F., Hekkert, M.P., Negro, S.O., 2011. Transition policy and innovation policy: Friends or foes? Environ. Innov. Soc. Transitions 1, 125–129. http://dx.doi.org/10.1016/j.eist.2011.04.009

Arrow, K., 1962. Economic welfare and the allocation of resources for invention, in: The Rate and Direction of Inventive Activity. Princeton University Press, Princeton, pp. 609–626.

Axsen, J., Goldberg, S., Melton, N., 2016. Canada's electric vehicle policy report card. Available at: https://sfustart.files.wordpress.com/2016/11/canadas-electric-vehicle-policy-report-card.pdf. Last accessed: 3/7/2017.

Azar, C., Sandén, B.A., 2011. The elusive quest for technology-neutral policies. Environ. Innov. Soc. Transitions 1, 135–139. http://dx.doi.org/10.1016/j.eist.2011.03.003

Bache, I., Flinders, M., 2004. Multi-level Governance. Oxford University Press. http://dx.doi.org/10.1093/0199259259.001.0001

Belgium Federal Government, 2017. National policy framework "alternative fuels infrastructure." Available at: http://www.benelux.int/files/6514/9302/1820/BELGIUM-NPF_alternative_fuels_infrastructure_2017_02_01_002.pdf.

Berg, B.L., Lune, H., 2011. Qualitative research methods for the social sciences, 8th ed. Pearson.

Bizberg, I., 2014. Types of capitalism in Latin America. Rev. Interv. économiques. Pap. Polit. Econ. 1–31.

Block, F., 2008. Swimming against the current: The rise of a hidden developmental state in the United States. Polit. Soc. 36, 169–206. http://dx.doi.org/10.1177/0032329208318731

BMVI, 2013. The mobility and fuels strategy of the German government. Available at: https://www.bmvi.de/SharedDocs/EN/Documents/MKS/mfs-strategy-final-en.pdf?__blob=publicationFile. Last accessed: 3/7/2017.

BMVI, 2009. German federal government's national electromobility development plan. Available at: https://www.now-gmbh.de/content/7-service/4-publikationen/3-modellregionen-elektromobilitaet/160408_germcalif-comparison_mit-titelseite.pdf. Last accessed: 3/7/2017.

Borrás, S., Edquist, C., 2013. The choice of innovation policy instruments. Technol. Forecast. Soc. Change 80, 1513–1522. http://dx.doi.org/10.1016/j.techfore.2013.03.002

Box, S., 2009. OECD work on innovation – A stocktaking of existing work, OECD Science, Technology and Industry Working Papers. http://dx.doi.org/10.1787/227048273721

Bryman, A., 2012. Social research methods, 4th ed. Oxford University Press, Oxford.

CEVforBC, 2016. Clean energy vehicle program. Available at: https://www.cevforbc.ca/clean-energy-vehicle-program Last accessed: 27/3/2017.

Challies, E.R.T., Murray, W.E., 2008. Towards post-neoliberalism? The comparative politico-economic transition of New Zealand and Chile. Asia Pac. Viewp. 49, 228–243. http://dx.doi.org/10.1111/j.1467-8373.2008.00372.x

CHFCA, 2010. 10 reasons to support hydrogen and fuel cell funding. Available at: http://www.chfca.ca/media/10_Reasons_Support_Funding.pdf. Last accessed: 3/7/2017.

Clift, B., Woll, C., 2012. The revival of economic patriotism, in: Morgan, G., Whitley, R. (Eds.), Capitalisms and Capitalism in the Twenty-First Century. Oxford University Press, Oxford, pp. 70–95. http://dx.doi.org/10.1093/acprof:oso/9780199694761.001.0001

Creswell, J.W., 2003. Research design: Qualitative, quantitative and mixed methods approaches. Sage Publications.

D'Costa, A.P., 2009. Economic nationalism in motion: Steel, auto, and software industries in India. Rev. Int. Polit. Econ. 16, 620–648. http://dx.doi.org/10.1080/09692290802467705

DBIS, 2013. Future of hydrogen powered cars mapped out. Available at: https://www.gov.uk/government/news/future-of-hydrogen-powered-cars-mapped-out. Last accessed: 3/7/2017.

DW, 2010. Berlin plugs in electric mobility strategy. Available at: http://www.dw.com/en/berlin-plugs-in-electric-mobility-strategy/a-5533192. Last accessed: 3/7/2017.

EAFO, 2017a. Fuel-cell electric vehicles. Available at: http://www.eafo.eu/eu -

eu_pev_fleet_fcev_graph_anchor. Last accessed: 3/7/2017.
EAFO, 2017b. Incentives & legislation. Available at: http://www.eafo.eu/incentives-legislation. Last accessed: 3/7/2017.
EEA, 2012. The contribution of transport to air quality. European Environment Agency, Copenhagen.
EIA, 2016. International energy outlook 2016 with projections to 2040. U.S. Energy Information Administration, Washington.
EU, 2013. Green Paper, A 2030 framework for climate and energy policies. EU, Brussels.
Flanagan, K., Uyarra, E., Laranja, M., 2011. Reconceptualising the "policy mix" for innovation. Res. Policy 40, 702–713. http://dx.doi.org/10.1016/j.respol.2011.02.005
Flick, U., 2009. An introduction to qualitative research, 4th ed. Sage Publications, Los Angeles.
Foxon, T., Pearson, P., 2008. Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. J. Clean. Prod. 16, S148–S161. http://dx.doi.org/10.1016/j.jclepro.2007.10.011
Galvin, P., Goracinova, E., Wolfe, D., 2015. Recent tends in manufacturing innovation policy for the automotive sector: A survey of the United States, Mexico, European Union, Germany and Spain, in: Nieuwenhuis, P., Wells, P. (Eds.), The Global Automotive Industry. John Wiley & Sons Ltd., Chichester, pp. 53–66. http://dx.doi.org/10.1002/9781118802366
Gunningham, N., Sinclair, D., 1999. Regulatory pluralism: Designing policy mixes for environmental protection. Law Policy 21, 49–76. http://dx.doi.org/10.1111/1467-9930.00065
H2-international, 2016. Incentives for 400,000 Battery and Fuel Cell Cars. Available at: https://www.h2-international.com/2016/08/17/eur-1-2-billion-incentives-for-400000-battery-and-fuel-cell-cars. Last accessed: 3/7/2017.
H2 Mobility Belgium, 2015. National implementation plan hydrogen refuelling infrastructure. Available at: http://hit-2-corridors.eu/wp-content/uploads/2015/01/NIP-Belgium.pdf. Last accessed: 3/7/2017.
Hall, P.A., Soskice, D., 2001. Variaties of Capitalism: The institutional foundations of comparative advantage. Oxford University Press, Oxford.
HARC, 2016a. U.S. hydrogen vehicles. Available at: http://hydrogen.pnl.gov/sites/default/files/data/US_Hydrogen-Fueled Vehicles_6.xlsx. Last accessed: 3/7/2017.
HARC, 2016b. International hydrogen vehicles. Available at: http://hydrogen.pnl.gov/sites/default/files/data/International Hydrogen Fueled Vehicles.xlsx. Last accessed: 3/7/2017.
Hauknes, J., Nordgren, L., 1999. Economic rationales of government involvement in innovation-related services. STEP 67, 44.
Hay, C., 2004. Ideas, interests and institutions in the comparative political economy of great transformations. Rev. Int. Polit. Econ. 11, 204–226. http://dx.doi.org/10.1080/0969229042000179811
Hekkert, M., van den Hoed, R., 2006. Competing technologies and the struggle towards a new dominant design: the emergence of the hybrid vehicle at the expense of the fuel-cell vehicle, in: Nieuwenhuis, P., Vergragt, P., Wells, P. (Eds.), The Business of Sustainable Mobility: From Vision to Reality. Greenleaf Publishing, Sheffield, pp. 45–60. http://dx.doi.org/10.9774/GLEAF.2350.2014.00010
het Vlaams Energieagentschap, 2017. Premie zero-emissie voertuigen. Available at: http://www.energiesparen.be/ZEV. Last accessed: 3/7/2017.
Hillman, A.J., Hitt, M.A., 1999. Corporate political strategy formulation: A model of approach, participation and strategy decisions. Acad. Manag. Rev. 24, 825. http://dx.doi.org/10.2307/259357
Howlett, M., 2009. Governance modes, policy regimes and operational plans: A multi-level nested model of policy instrument choice and policy design. Policy Sci. 42, 73–89. http://dx.doi.org/10.1007/s11077-009-9079-1
Howlett, M., Rayner, J., 2007. Design principles for policy mixes: Cohesion and coherence in "new governance arrangements." Policy Soc. 26, 1–18. http://dx.doi.org/10.1016/S1449-4035(07)70118-2
HTAC, 2014. Annual Report on Hydrogen and Fuel Cell Commercialization and Technical

Development. Available at: https://www.hydrogen.energy.gov/pdfs/2014_htac_annual_report.pdf. Last accessed: 3/7/2017.
ICCT, 2016. Comparison of leading electric vehicle policy and deployment in Europe. International Council on Clean Transportation, Berlin.
ICCT, 2015. A comparative analysis of electric-drive policy in Germany and California. International Council on Clean Transportation, Berlin.
Icelandic New Energy, 2012. INTELLECT - End of project report. Available at: http://newenergy.is/gogn/skyrslur/intelect_final_report.pdf. Last accessed: 3/7/2017.
IEA-HEV, 2016. Hybrid and electric vehicles - The electric drive commutes.
IPCC, 2014. Climate change 2014: Mitigation of climate change, Working Group III contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York.
IPCC, 2013. Climate change 2013: The physical science basis, Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York.
IPCC, 2007. Climate change 2007: Impacts, adaptation and vulnerability, Working Group II contribution to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York.
IPHE, 2016a. Iceland country update May 2016. Available at: http://iphe.net/docs/Meetings/SC25/25-SC-Statement-Iceland.pdf Last accessed: 23/3/2017.
IPHE, 2016b. Canada country update November 2016. Available at: http://iphe.net/docs/Meetings/SC26/26-SC-Statement-Canada.pdf. Last accessed: 3/7/2017.
IPHE, 2016c. UK country update April 2016. Available at: http://www.iphe.net/docs/Meetings/SC25/25-SC-Statement-United-Kingdom.pdf. Last accessed: 3/7/2017.
IPHE, 2015a. Germany country ppdate December 2015. Available at: http://iphe.net/docs/Meetings/SC24/Countries/IPHE Country Update December 2015 Germany.pdf. Last accessed: 3/7/2017.
IPHE, 2015b. Japan country update December 2015. Available at: http://iphe.net/docs/Meetings/SC24/Countries/IPHE Country Update November 2015 Japan.pdf. Last accessed: 3/7/2017.
IPHE, 2011. Hydrogen and fuel cell global policies update. Available at: http://www.iphe.net/docs/iphe_policy_update_120911_web.pdf Last accessed: 24/3/2017.
Jackson, G., Deeg, R., 2012. The long-term trajectories of institutional change in European capitalism. J. Eur. Public Policy 19, 1109–1125. http://dx.doi.org/10.1080/13501763.2012.709001
JAMA, 2009. Japan's measures to withstand impact of global crisis on its automotive industry. Available at: http://www.jama-english.jp/asia/news/2009/vol36/index.html. Last accessed: 3/7/2017.
Kay, A., 2006. The dynamics of public policy: Theory and evidence. Edward Elgar Publishing, Cheltenham.
Kemp, R., Rotmans, J., 2004. Managing the transition to sustainable mobility, in: Elzen, B., Geels, F.W., Green, K. (Eds.), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Edward Elgar, Cheltenham, pp. 137–167. http://dx.doi.org/10.4337/9781845423421
Kemp, R., Schot, J., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. Technol. Anal. Strateg. Manag. 10, 175–198. http://dx.doi.org/10.1080/09537329808524310
Kern, F., Kivimaa, P., Martiskainen, M., 2017. Policy packaging or policy patching? The development of complex energy efficiency policy mixes. Energy Res. Soc. Sci. 23, 11–25. http://dx.doi.org/10.1016/j.erss.2016.11.002
Kern, F., Smith, A., 2008. Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. Energy Policy 36, 4093–4103. http://dx.doi.org/10.1016/j.enpol.2008.06.018
Krippendorff, K., 2004. Reliability in content analysis. Hum. Commun. Res. 30, 411–433. http://dx.doi.org/10.1111/j.1468-2958.2004.tb00738.x
Laranja, M., Uyarra, E., Flanagan, K., 2008. Policies for science, technology and innovation:

Translating rationales into regional policies in a multi-level setting. Res. Policy 37, 823–835. http://dx.doi.org/10.1016/j.respol.2008.03.006
Lazonick, W., 2011. The innovative enterprise and the development state: Towards an economics of "organization success." INET Annu. 2011 Conf.
LeCompte, M.D., Goetz, J.P., 1982. Problems of reliability and validity in ethnographic research. Rev. Educ. Res. 52, 31–60. http://dx.doi.org/10.3102/00346543052001031
Lepori, B., van den Besselaar, P., Dinges, M., Potì, B., Reale, E., Slipersæter, S., Thèves, J., van der Meulen, B., 2007. Comparing the evolution of national research policies: what patterns of change? Sci. Public Policy 34, 372–388. http://dx.doi.org/10.3152/030234207X234578
Lior, N., 2012. Sustainable energy development (May 2011) with some game-changers. Energy 40, 3–18. http://dx.doi.org/10.1016/j.energy.2011.09.044
Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. Res. Policy 41, 955–967. http://dx.doi.org/10.1016/j.respol.2012.02.013
McKinsey, 2010. A portfolio of power-trains for Europe: a fact-based analysis. McKinsey & Company.
METI, 2014a. Japan's initiatives for the diffusion of next-generation vehicles. Available at: http://www.cev-pc.or.jp/english/events/okinawa2014/02.pdf. Last accessed: 3/7/2017.
METI, 2014b. Summary of the strategic road map for hydrogen and fuel cells. Available at: http://www.meti.go.jp/english/press/2014/pdf/0624_04a.pdf. Last accessed: 3/7/2017.
Mikler, J., Harrison, N.E., 2012. Varieties of Capitalism and technological innovation for climate change mitigation. New Polit. Econ. 17, 179–208. http://dx.doi.org/10.1080/13563467.2011.552106
Ministerie van Financiën, 2011. Autobrief. Available at: https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2011/06/01/autobrief/autobrief.pdf. Last accessed: 3/7/2017.
NCSL, 2015. State efforts promote hybrid and electric vehicles. Available at: http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx. Last accessed: 24/3/2017.
NEDO, 2014. Hydrogen infrastructure in Japan. Available at: https://www.hydrogen.energy.gov/pdfs/review14/h2in_watanabe_2014_o.pdf. Last accessed: 3/7/2017.
Nölke, A., Vliegenthart, A., 2009. Enlarging the Varieties of Capitalism: The emergence of dependent market economies in East Central Europe. World Polit. 61, 670–702. http://dx.doi.org/10.1017/S0043887109990098
Norwegian Hydrogen Forum, 2016. The Norwegian hydrogen guide. Available at: http://www.hydrogen.no/NHF_Hydrogenguiden_2016.pdf. Last accessed: 3/7/2017.
OICA, 2015. Economic contributions. Available at: http://www.oica.net/category/economic-contributions/facts-and-figures. Last accessed: 3/7/2017.
OLEV, 2014. Investing in ultra low emission vehicles in the UK, 2015 to 2020. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307019/ulev-2015-2020.pdf. Last accessed: 3/7/2017.
Oliver, C., Holzinger, I., 2008. The effectiveness of strategic political management: A dynamic capabilities framework. Acad. Manag. Rev. 33, 496–520. http://dx.doi.org/10.5465/AMR.2008.31193538
Oost, H., 2006. Circling around a research question: defininig your research question. Universiteit Utrecht, Utrecht.
Pollet, B.G., Staffell, I., Shang, J.L., 2012. Current status of hybrid, battery and fuel cell electric vehicles: From electrochemistry to market prospects. Electrochim. Acta 84, 235–249. http://dx.doi.org/10.1016/j.electacta.2012.03.172
Rogge, K.S., Reichardt, K., 2016. Policy mixes for sustainability transitions: An extended concept and framework for analysis. Res. Policy 45, 1620–1635. http://dx.doi.org/10.1016/j.respol.2016.04.004
Romm, J., 2006. The car and fuel of the future. Energy Policy 34, 2609–2614. http://dx.doi.org/10.1016/j.enpol.2005.06.025
Salamon, L.M., 2000. The new governance and the tools of public action: An introduction. Fordham

Urban Law J. 28, 1–47.
Salmenkaita, J.-P., Salo, A., 2002. Rationales for government intervention in the commercialization of new technologies. Technol. Anal. Strateg. Manag. 14, 183–200. http://dx.doi.org/10.1080/09537320220133857
Sandén, B.A., Azar, C., 2005. Near-term technology policies for long-term climate targets—economy wide versus technology specific approaches. Energy Policy 33, 1557–1576. http://dx.doi.org/10.1016/j.enpol.2004.01.012
Schmidt, V.A., 2003. French capitalism transformed, yet still a third variety of capitalism. Econ. Soc. 32, 526–554. http://dx.doi.org/10.1080/0308514032000141693
Schmidt, V.A., 2002. The Futures of European Capitalism. Oxford University Press.
Schneider, B.R., 2009. Hierarchical market eonomies and Varieties of Capitalism in Latin America. J. Lat. Am. Stud. 41, 553–575. http://dx.doi.org/10.1017/S0022216X09990186
Sierzchula, W., Bakker, S., Maat, K., van Wee, B., 2014. The influence of financial incentives and other socio-economic factors on electric vehicle adoption. Energy Policy 68, 183–194. http://dx.doi.org/10.1016/j.enpol.2014.01.043
Smith, M., 2004. Toward a theory of EU foreign policy-making: multi-level governance, domestic politics, and national adaptation to Europe's common foreign and security policy. J. Eur. Public Policy 11, 740–758. http://dx.doi.org/10.1080/1350176042000248124
Smits, R., Kuhlmann, S., Teubal, M., 2010. A system-evolutionary approach for innovation policy, in: Smits, R.E., Kuhlmann, S., Shapira, P. (Eds.), The Theory and Practice of Innovation Policy: An International Research Handbook. Edward Elgar Publishing, Cheltenham, pp. 417–448. http://dx.doi.org/10.4337/9781849804424
TFL, 2017. Congestion Charge. Available at: https://tfl.gov.uk/modes/driving/congestion-charge. Last accessed: 3/7/2017.
Tuominen, A., Himanen, V., 2007. Assessing the interaction between transport policy targets and policy implementation—A Finnish case study. Transp. Policy 14, 388–398. http://dx.doi.org/10.1016/j.tranpol.2007.04.002
UK Government, 2017. Low-emission vehicles eligible for a plug-in grant. Available at: https://www.gov.uk/plug-in-car-van-grants/what-youll-get. Last accessed: 3/7/2017.
UK H2 Mobility, 2013. Phase 1 Results. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/192440/13-799-uk-h2-mobility-phase-1-results.pdf. Last accessed: 3/7/2017.
Weber, K.M., Rohracher, H., 2012. Legitimizing research, technology and innovation policies for transformative change. Res. Policy 41, 1037–1047. http://dx.doi.org/10.1016/j.respol.2011.10.015
Wesseling, J.H., 2016. Explaining variance in national electric vehicle policies. Environ. Innov. Soc. Transitions 1–11. http://dx.doi.org/10.1016/j.eist.2016.03.001
Wesseling, J.H., Faber, J., Hekkert, M.P., 2014. How competitive forces sustain electric vehicle development. Technol. Forecast. Soc. Change 81, 154–164. http://dx.doi.org/10.1016/j.techfore.2013.02.005
Wesseling, J.H., Farla, J.C.M., Hekkert, M.P., 2015. Exploring car manufacturers' responses to technology-forcing regulation: The case of California's ZEV mandate. Environ. Innov. Soc. Transitions 16, 87–105. http://dx.doi.org/10.1016/j.eist.2015.03.001
Woolthuis, R.K., Lankhuizen, M., Gilsing, V., 2005. A system failure framework for innovation policy design. Technovation 25, 609–619. http://dx.doi.org/10.1016/j.technovation.2003.11.002
Yin, R., 2003. Case Study Research, 3rd ed. Sage Publications, Thousand Oaks, CA.

Appendix A: operationalization table

Concept	Indicators		Data source
Policy instrument	Type of instrument	Regulatory	Policy and IPHE documents, interview data
		Economic	
		Soft	
	Focus of instrument	Supply-side	
		Demand-side	
	Combination of instruments (mix)		
Policy goal	Type of objective	Content	Policy and IPHE documents, interview data
		Process/learning	
	Concrete target		
	Type of target	Environmental	
		Social	
		Economic	
	Actors targeted		
	Processes targeted		
Policy rationale	Market failure		Policy and IPHE documents, interview data
	Structural system failure		
	Transformational system failure		
Political influence strategy of car manufacturers	Opposition		Policy and IPHE documents, interview data
	Slow down		
	Support		
	Progressive		
Previously implemented policies	Complementary		Policy and IPHE documents, interview data
	Incompatible		
	Technology neutral or specific		
Dispersal of power	Formulation/implementation of policies		Policy and IPHE documents, interview data
	Responsibility for policies		
	Policy initiatives		
National context	Industrial activities		Policy and IPHE documents, interview data
	Natural resources		

Appendix B: interview guide

- Before start of interview:
    - I would like to record this interview so that I can later transcribe it and make use of it while proceeding with this research. Do you give permission for this interview to be recorded?

- Icebreaking questions:
    - Could you describe some of the issues you are working on these days?
    - How are you involved in FCEV policy making?

- Specific questions on independent variables:
    - **Policy goals**
        - What are the goals that your FCEV policy can help achieve?
        - In attaining these goals, is there a focus on a specific technology (BEV, FCEV, PHEV etc.) or is the policy directed on the performance of these cars (e.g. actual/zero-emission)? Why or why not?
            - If ZEVs are mentioned, does this include FCEVs? What is the role of FCEVs in this ZEV mix? Why are FCEVs important/not important?

    - **Policy instruments**
        - Which policy instruments are used for FCEVs? Why were these instruments selected?
        - How do these policy instruments help in achieving the set policy goal?
        - Do you think other types of policy might have been as effective for your purposes? Was there a reason why they/these were not used?

    - **Policy rationale**

      In my research, I have identified three reasons why specific FCEV policy instruments might be deemed necessary. I will give a short explanation of each and then ask whether this is the reason for the presence of FCEV policies in your country and why or why not.
        - *Market failures: policies are necessary to correct market failures where societal benefits outweigh the benefits of the investor. Intervention is viewed as necessary to correct for this imbalance and provide the full societal value to the investor*. Does this apply to your country? Why or why not?
        - *Structural system failures: policies are necessary to develop or optimize the FCEV innovation system by, for example, improving cooperation amongst firms and research institutes. This system development or optimization is a task often taken on by the government*. Does this apply to your country? Why or why not?
        - *Transformational system failures: policies are necessary to help move away from incumbent technologies such as ICE vehicles to new technologies like FCEVs. Governments can actively facilitate this transition with such policies*. Does this apply to your country? Why or why not?

- **Previously implemented policies**
  - Are there existing policy instruments in place in your country, other than specific FCEV or ZEV policies, that can help or cause an imbalance in the efficiency and effectiveness of FCEV policies? How?
  - Are existing vehicle technologies, for example internal combustion engine (ICE) vehicles, supported? How and why?

- **Political influence strategy of car manufacturers**
  - Is there a general approach in the formulation of policy to do extensive consultations with car manufacturers? Has there been an interest and maybe some kind of role from car manufacturers?
  - What is their overall view on the policy instruments? In other words, do your industry stakeholders think that your country has the right policy mix to make significant progress in the deployment of FCEVs? If not, why not?
  - Do you think your industry supports or also opposes some policy instruments? How do you think they would like to see the policy changed?
  - How do policy makers deal with this dynamic?

- **Dispersal of power**
  - On which level(s) of government (national, regional, local) are the most FCEV policies formulated and implemented?
  - *For EU countries*: what is the influence of EU policy/regulation, like directives such as the 'clean power for transport'?
  - *For non-EU countries:* What is the influence of international agreements like emission standards on the way you formulate FCEV policy?
  - Are there any FCEV policies formulated and/or implemented on sub-national level? How do these relate to national FCEV policies?
  - Which ministries are responsible for specific FCEV policies or policies that can have an impact on FCEV deployment?
  - Is there coordination across ministries? Does this help formulation and/or implementation of FCEV policies? Why or why not?
  - Is there any form of coordination across levels of government (regional, local)?

- **Contextual factors**
  - Are there any natural resources that are influencing or being taken into consideration when developing the national or regional ZEV/FCEV approach? For example, is there geothermal energy which can be used to convert hydrogen for usage as vehicle fuel?
  - Are there any industrial sectors/activities in your country that might influence a specific focus on FCEVs? For example, is hydrogen produced in oil refineries which could be used as passenger vehicle fuel?

Appendix C: RD&D subsidies for hydrogen and fuel cells in 2010-2014

Country	RD&D subsidies (million USD)
Australia	8,40
Austria	24,99
Belgium	5,46
Canada	132,53
Czech Republic	5,12
Denmark	145,24
Finland	0
France	232,47
Germany	142,12
Greece	1,16
Hungary	0
Iceland	no data
Ireland	1,19
Italy	88,75
Japan	512,22
Korea	191,87
Latvia	no data
Luxembourg	3,44
Mexico	no data
the Netherlands	6,88
New Zealand	3,98
Norway	50,14
Poland	23,37
Portugal	1,56
Slovak Republic	1,65
Slovenia	no data
Spain	33,67
Sweden	15,72
Switzerland	128,37
Turkey	3,62
United Kingdom	136,80
United States	1062,62

Source: IEA

Appendix D: demand-side incentives in-depth analysis countries

Country	Demand-side incentives
Belgium	**Tax incentives:** lower circulation tax (ACEA, 2016) **Purchase subsidy:** none at the national level. Flanders provides purchase subsidy of up to 4,000 euro (het Vlaams Energieagentschap, 2017) **Infrastructure incentives:** none at the national level. Regional benefits including tax benefit for investment and production (H2 Mobility Belgium, 2015) **Non-financial incentives:** some cities offer free parking, exemption from road fee and access to carpool and bus lanes (H2 Mobility Belgium, 2015)
California	**Tax incentives:** none **Purchase subsidy:** 5,000 dollar purchase subsidy (ICCT, 2015) **Infrastructure incentives:** budget available for the roll-out on hydrogen refuelling infrastructure (ICCT, 2015) **Non-financial incentives:** access to HOV lanes with single-occupant, free parking in some communities/cities (ICCT, 2015)
Canada	**Tax incentives:** none at the national level. **Purchase subsidy:** none at the national level. British Columbia provides purchase subsidy of up to 6.000 dollars (IPHE, 2016b) **Infrastructure incentives:** Support for the deployment of 3 hydrogen refuelling stations (IPHE, 2016b) **Non-financial incentives:** some provinces provide HOV lane access (Axsen et al., 2016)
Germany	**Tax incentives:** exemption of road tax for 10 years (ICCT, 2015) **Purchase subsidy:** from 2016 onwards, purchase subsidy of 2.000 euro if industry also provides 2.000 euro. Total subsidy thus 4.000 euro (H2-international, 2016) **Infrastructure incentives:** funds for operation and installation of refuelling stations (IPHE, 2015a) **Non-financial incentives:** regional governments may decide to implement various forms like free parking and access to carpool and bus lanes (ICCT, 2015)
Iceland	**Tax incentives:** no import and VAT tax (IPHE, 2016a) **Purchase subsidy:** none **Infrastructure incentives:** no taxes on fuel (IPHE, 2016a) **Non-financial incentives:** free parking in some cities (Icelandic New Energy, 2012)
Japan	**Tax incentives:** exemption registration and ownership tax (JAMA, 2009) **Purchase subsidy:** purchase subsidy for purchase of the vehicle (IPHE, 2015b) **Infrastructure incentives:** subsidies provided for up to 50% of the installation costs (NEDO, 2014) **Non-financial incentives:** additional subsidy provided locally by Tokyo (HTAC, 2014)
the Netherlands	**Tax incentives:** exempt from registration and circulation tax, benefits for private use of company car (Ministerie van Financiën, 2011) **Purchase subsidy:** none **Infrastructure incentives:** none **Non-financial incentives:** none
Norway	**Tax incentives:** exemption from registration tax and VAT, low road tax (Norwegian Hydrogen Forum, 2016) **Purchase subsidy:** none **Infrastructure incentives:** none with a specific focus on hydrogen (Norwegian Hydrogen Forum, 2016) **Non-financial incentives:** free parking, free pass through toll roads, free transport on public ferries, access to carpool and bus lanes (Norwegian Hydrogen Forum, 2016)
United Kingdom	**Tax incentives:** none **Purchase subsidy:** vehicle purchase subsidy of up to £4,500 (UK Government, 2017) **Infrastructure incentives:** capital grant provided (up to 60% for new stations, 100% for upgrades) (IPHE, 2016c) **Non-financial incentives:** exemption from congestion fee in London (TFL, 2017)