Energy security in China

Fuel cell vehicles, plug-in electric vehicles and policy responses to oil imports

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Abstract

In 1993, China lost its position as net oil exporter due to its rapid economic growth. Having been self-reliant in oil for thirty years, this came as a shock to the Chinese government, that traditionally perceived oil import dependency as the greatest threat to China's energy security. Realizing that China did not have enough domestic oil reserves to reverse this situation, the Chinese government embarked on an ambitious quest to replace all petrol-driven vehicles with plug-in electric vehicles. Nowadays, China is spearheading this global transition and there is little disagreement among scholars that plug-in electric vehicles are regarded by the Chinese government as China's most important energy security strategy. However, the launch of various ambitious fuel cell vehicle policies alongside the government's announcement to phase-out subsidies for plug-in electric vehicles have put this hypothesis into doubt. This research examines whether the Chinese government has come to regard fuel cell vehicles as the most potent solution to reduce China's oil import dependency at the expense of plug-in electric vehicles.

Keywords

Energy security, fuel cell vehicles, plug-in electric vehicles, energy policy, perception, national security, China, Chinese government, lithium-ion batteries

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List of abbreviations

BEV – battery electric vehicle: a fully electric vehicle with a battery pack

CNG – compressed natural gas

EU – European Union

FCV – fuel cell vehicle: an electric vehicle that uses hydrogen as fuel

FYP – Five-Year Plan: China's five-yearly roadmaps determining the country's course

GHG – greenhouse gasses

ICEV – internal combustion engine vehicle

LIB – lithium-ion battery: battery used in plug-in electric vehicles

LNG – liquefied natural gas

MIC2025 – Made in China 2025: influential Chinese manufacturing roadmap

MIIT – Ministry of Industry and Information Technology: Chinese ministry

MoST – Ministry of Science and Technology: Chinese ministry

NDRC: National Development and Reform Commission: Chinese ministry-level macroeconomic management agency

NEV – new energy vehicle: official Chinese collective name for battery electric vehicle, plug-in hybrid electric vehicle and fuel cell vehicle

NOC – national oil company

PEV – plug-in electric vehicle: a collective name for battery electric vehicle and plug-in hybrid electric vehicle

R&D – research and development

US – United States of America

USD – United States Dollar

ZEV – zero emission vehicle: widely used collective name for battery electric vehicles, plug-in hybrid electric vehicles and fuel cell vehicles

Introduction

The global number of plug-in electric vehicles (PEVs) is rising fast and there is little doubt among experts that, in the coming decades, they will gradually displace vehicles with an internal combustion engine (ICEVs). With 777.000 sales in 2017, the People's Republic of China now constitutes more than half of the global PEV market. The fact that China is leading the transition towards PEVs has almost entirely been the result of highly ambitious policies and has been linked by experts to four factors: reducing air pollution in Chinese cities; slowing down human-induced climate change; transforming China into the global market leader of the automotive industry of the future; and, lastly, enhancing *energy security*.

The first three factors generally receive the most attention and are often cited by journalists and academics as the primary drivers for China's car electrification. Günther et al., Hao et al. and Tyfield and Zuev emphasize the impact of environmental drivers, whereas Bohnsack and Wang et al. point towards economic and industrial ambitions.[1] However, when looking more closely at Chinese PEV policies, it becomes clear that energy security is a dominant theme in the most relevant policy documents. It is either mentioned explicitly or becomes apparent due to the abundance of energy security-related issues in them. Energy security has been defined as an 'uninterrupted availability of energy sources at an affordable price' by various authoritative sources.[2] In the context of energy security as a driver for PEVs in China, oil is always the point of attention, as is illustrated in the works of Du and Ouyang, Gong et al. and Liu et al.[3]

The reason why the government regards oil as problematic, other than it being a major source of greenhouse gas emissions (GHGs), is because Chinese demands for oil imports have been rapidly growing since the 1990s. This is mostly the result of four decades of unprecedented economic and industrial growth that brought large amounts of wealth to China's citizens, which allowed them to buy

[1] H.-O. Günther, M. Kannegiesser and N. Autenrieb, 'The role of electric vehicles for supply chain sustainability in the automotive industry', *Journal of Cleaner Production* 90 (2015) 220-233, 220, 223, 232; and: Han Hao, Xiang Cheng, Zongwei Liu and Fuquan Zhao, 'China's traction battery technology roadmap: Targets, impacts and concerns', *Energy Policy* 108 (2017) 355-358, 355; and: David Tyfield and Dennis Zuev, 'Stasis, dynamism and emergence of the e-mobility system in China: A power relational perspective, '*Technological Forecasting & Social Change* 126 (2018) 259-270, 259, 267; and: René Bohnsack, 'Local niches and firm responses in sustainability transitions: The case of low-emission vehicles in China', *Technovation* 70-71 (2018) 20-32, 20; and: Yunshi Wang, Daniel Sperling, Gil Tal and Haifeng Fang, 'China's electric car surge', *Energy Policy* 102 (2017) 486-490, 490.

[2] Daniel Yergin, 'Energy Security in the 1990s', *Foreign Affairs* 67 (1988) 110-132, 111; and: J. Bielecki, 'Energy security: is the wolf at the door?', *The Quarterly Review of Economics and Finance* 42 (2002) 235-250, 237; and: *International Energy Agency*, 'Energy Security' (Version 13 December 2018) https://www.iea.org/topics/energysecurity/ 13 December 2018.

[3] Liuyu Du and Danhua Ouyang, 'Progress of Chinese electric vehicles industrialization in 2015 : A review', *Applied Energy* 188 (2017) 529-546, 530; and: Huiming Gong, Michael Q. Wang and Hewu Wang, 'New energy vehicles in China: policies, demonstration and progress', *Mitigation and Adaption Strategies for Global Change* 18 (2013) 207-228, 208; and: Zongwei Liu, Han Hao, Xiang Cheng and Fuquan Zhao, 'Critical issues of energy efficient and new energy vehicles development in China', *Energy Policy* 115 (2018) 92-97, 92.

tens of millions of vehicles almost overnight. Consequently, the demand for oil surged and transformed the country from a net exporter of oil into the world's largest importer.[4] China's demand for imported oil is still growing rapidly and the majority of scholars -including renowned scholar Daniel Yergin- agree that this constitutes the government's first and foremost energy security concern.[5]

However, importing oil is not very uncommon so why is it so problematic for the Chinese government? Explanations of scholars vary and include the crucial role that oil plays in the continued economic expansion of developing countries within a world where oil disruptions are commonplace; the chronic instability of China's main oil suppliers; and security hazards that jeopardize vital maritime chokepoints and sea-lanes.[6] Striking is that China's fear for intervention by the United States (US) is often linked to these various explanations, as they are either involved in or responsible for the instability of China's oil supplying regions or perceived as a direct threat towards China's supply-chain.[7]

However, the explanations mentioned above merely describe the symptoms and do not explain the source of China's almost paranoid fixation on securing its oil supply-chain. In this regard, the hypotheses by Leung et al. and Yergin are the most convincing ones. They point out that this obsession is the result of deeply-rooted historical experiences that have shaped Chinese policies and energy security perceptions until this day. According to them, some of China's most traumatic chapters -the *Century of Humiliation*, the Korean War and the Sino-Soviet Split- are inextricably tied to China's most severe oil crises and shortages. During these events, China's dependence on oil imports was regarded as its Achilles heel and often targeted by the major powers to cripple and -according to the communist leadership- deny China its right to independence. This convinced the government of the absolute necessity of self-reliance, which eventually led to China becoming an oil producer and net exporter in 1963.[8] Unsurprisingly, China's return to a dependency on oil imports in 1993 was met with horror by the Chinese leadership. Kardon, Leung et al., Yao and Chang and

[4] Isaac B. Kardon, 'Oil for the Lamps of China: Managing Uncertainty and Vulnerability in World Energy Markets, *Journal of Global Policy and Governance* 2 (2013) 2, 305-328, 319; and: U.S. Energy Information Administration, 'China is now the world's largest net importer of petroleum and other liquid fuels' (Version 24 March 2014) https://www.eia.gov/todayinenergy/detail.php?id=15531 13 December 2018.

[5] Kardon, 'Oil for the Lamps of China', 305-328; 314, 316; and: Guy C.K. Leung, Aleh Cherp, Jessica Jewell and Yi-Ming Wei, 'Securitization of energy supply chains in China', *Applied Energy* 123 (2014) 316-326, 325; and: Daniel Yergin, *The Quest: Energy, security, and the remaking of the modern world* (London 2012) 196-199.

[6] Xiao-Bing Zhang, Ping Qin and Xiaolan Chen, 'Strategic oil stockpiling for energy security: The case of China and India', *Energy Economics* 61 (2017) 253-260, 253, 259; and: Henelito A. Sevilla, 'The Arab Spring and South China Sea Tensions: Analyzing China's Drive to Energy Security', *Turkish Journal of International Relations* 12 (2013) 3, 94-107, 94, 96-98; and: ZhongXiang Zhang, 'China's energy security, the Malacca dilemma and responses, '*Energy Policy* 39 (2011) 11, 7612-7615, 7613.

[7] Kardon, 'Oil for the Lamps of China', 309; and: Sevilla, 'The Arab Spring and South China Sea Tensions', 96-98, 100-101.

[8] Daniel Yergin, *The Quest*, 198.

Yergin describe a wide variety of policy responses that aimed to slow down the rapid increase of oil imports that already constituted 39% of China's total oil consumption just one decade later.[9]

Among those responses was a government decree that ordered the launch of a research and development (R&D) program for PEVs. This was the first step towards China's domination of what would become a market worth of billions of euros.[10] From the onset, it seems logical that PEVs play a key-role in China's renewed quest for self-reliance. Their energy comes directly from China's electricity grid and can be generated from multiple domestic sources (coal, nuclear energy and renewables like hydro-, solar and wind power). Therefore, PEVs do, theoretically, not require energy sources from far-flung and instable regions, which makes them a much more energy secure mode of transport than ICEVs. However, focusing solely on the electricity feedstock is too narrow and ignores one very important aspect of PEVs: the battery.

All PEVs require a battery pack to store and distribute energy to the traction motor and this makes batteries the defining feature of the vehicle. A wide variety of battery types exist, but just one type is powerful and economically viable enough to be used in vehicles: the lithium-ion battery (LIB). LIBs rely on various metals like lithium, cobalt, graphite, manganese and nickel and these minerals happen to be scarce and geographically dispersed. As it turns out, energy security scholars tend to focus primarily on traditional energies (oil, coal and gas) and renewables, but the supply chain of supporting materials that are vital to certain energy systems are only rarely examined. This makes sense, because rare metals are technically no energy sources and their use in vehicles is a fairly recent phenomenon. Before that, LIBs were (and still are) mostly used in consumer electronics that do not exactly fit into an energy security narrative. Perhaps the most important reason for the absence of rare metals in the energy security discourse is the small share of PEVs in the global vehicle stock (3,1 million PEVs compared to 1,2 billion ICEVs).[11]

Nevertheless, the share of PEVs in both China and the rest of the world will rise rapidly in the coming years and batteries and their components should therefore be included in the energy security debate. Research on the global supply chain of rare metals and LIBs does exist and provides valuable information about the potential of supply bottlenecks or other crises. However, they do not take into consideration the energy security dimension, let alone the Chinese government's perception of energy security (PEVs as a solution for China's increasing dependency on imported oil). Notwithstanding, the insights are both valuable and alarming. Jaffe, Miedema and Moll, Olivetti et al., Richa et al., Sverdrup and Sverdrup and Ragnarsdottir have all concluded that the ongoing surge of PEVs is likely to become problematic in the future. They argue that cobalt, graphite, lithium and nickel constitute

[9] Kardon, 'Oil for the Lamps of China', 318-319; Leung et al., 'Securitization of energy supply chains in China', 318-319, 322; and: Lixia Yao and Youngho Chang, 'Shaping China's energy security: The impact of domestic reforms', *Energy Policy* 77 (2015) 131-139, 133-134; and Yergin, *The Quest*, 202-205
[10] Gong et al., 'New energy vehicles in China', 210.
[11] *International Energy Agency*, 'Global EV Outlook 2018: Towards cross-modal electrification' (2018) 111.

liabilities due to either scarcity, geographical disparity, the political instability of the producing regions, the challenges of LIB recycling or the threat that demand will outpace global production capacity.[12] Hao et al. regard the lithium supply chain as particularly worrisome for China, as it consumes half of the world's produced lithium and has to import 86% of it.[13] The same is true for cobalt and this has a real potential to dampen the government's enthusiasm for PEVs.[14]

On top of this come additional complications: LIBs have a relatively short range, a limited lifespan, perform badly in cold weather conditions, are difficult to recycle and suffer from permanent discharge – meaning that they 'leak' energy over time. This makes LIBs problematic for heavy-duty and military applications, which is likely to be regarded as a liability by the Chinese government. In addition, PEVs require enormous amounts of electricity to function properly and there is some uncertainty whether electricity grids can support large amounts of PEVs.[15] Smart grids have the potential to alleviate the threats of disruptions and blackouts, but make the grid vulnerable to cybersecurity attacks as well, creating an additional energy security challenge for the Chinese government.

Given their deeply-rooted obsession with the safeguarding of its energy flows, the rising uncertainties surrounding PEVs are likely to constitute an energy security dilemma for the Chinese government if they have not caused one already. Nevertheless, despite the growing body of literature focusing on the shortcomings of LIBs, it has yet to connect these to energy security or focus on what the Chinese government might perceive as viable alternatives to PEVs. The huge stakes that the Chinese government has in its PEV and battery sector make it obvious that China will invest in the research and development of battery technologies that are less dependent on precious minerals. Nevertheless, a scenario wherein alternative battery packs will replace the superior LIBs seems far away and this makes it plausible that China is currently looking beyond PEVs for a more energy secure solution.[16]

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[12] Sam Jaffe, 'Vulnerable Links in the Lithium-Ion Battery Supply Chain', *Joule* 1 (2017) 220-228; and: Jan H. Miedema and Henri C. Moll, 'Lithium availability in the EU27 for battery-driven vehicles: The impact of recycling and substitution on the confrontation between supply and demand until 2050', *Resources Policy* 38 (2013) 2, 204-211; and: Elsa A. Olivetti, Gerbrand Ceder, Gabrielle G. Gaustad and Xinkai Fu, 'Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals', *Joule* 1 (2017) 229-243; and: Kirti Richa, Callie W. Babbitt, Gabrielle Gaustad and Xue Wang, 'A future perspective on lithium-ion battery waste flows from electric vehicles', *Resources, Conservation and Recycling* 83 (2014) 63-76; and: Harald Ulrik Sveldrup, 'Modelling global extraction, supply, price and depletion of the extractable geological resources within the LITHIUM model', *Resources, Conservation and Recycling* 114 (2016) 112-129; and: Harald Ulrik Sverdrup and Kristin Vala Ragnarsdottir, 'Modelling the global primary extraction, supply, price and depletion of the extractable geological resources using the cobalt model', in: Christian Ludwig and Cecilia Matasci (ed.), *Boosting Resource Productivity: by Adopting the Circular Economy* (Villigen 2017) 90-99.

[13] Han Hao, Zongwei Liu, Fuquan Zhao, Yong Geng and Joseph Sarkis, 'Material flow analysis of lithium in China', *Resources Policy* (2017) 100-106.

[14] Henry Sanderson, 'China plays long game on cobalt and electric batteries', *Financial Times*, (version 26 May 2016) https://www.ft.com/content/054bbb3a-1e8b-11e6-a7bc-ee846770ec15, 31 December 2018.

[15] Kevin Bullis, 'Could Electric Cars Threaten the Grid?', *MIT Technology Review*, (version 16 August 2013) https://www.technologyreview.com/s/518066/could-electric-cars-threaten-the-grid/, 31 December 2018.

[16] Jaffe, 'Vulnerable Links in the Lithium-Ion Battery Supply Chain', 226-227; and: Luis Oliveira, Maarten Messagie, Surendraprabu Rangaraju, Javier Sanfelix, Maria Hernandez Rivas and Joeri van Mierlo, 'Key issues of

One alternative that might take away the looming uncertainties that surround PEVs does in fact exist. Fuel cell vehicles (FCVs[17]) are powered through an electrochemical reaction between hydrogen and oxygen in a fuel cell instead of using a battery. By producing only water vapor as waste product, FCVs do not emit GHGs and the hydrogen that is necessary to fuel these vehicles can be extracted from virtually every power source, including renewables. This naturally means that FCVs have the potential to become a clean alternative for PEVs and their engines consist out of key components that rely much less on the use of metals that are either scarce or hard to mine.[18]

However, FCVs lag significantly behind PEVs in terms of research, development, deployment, infrastructure and investment. This means that the global FCV stock is much smaller and that one vehicle is a lot more expensive than its fossil fuel or battery-powered counterparts. Moreover, with just over a thousand units and an inferior understanding of FCV technology, China is lagging behind leading players such as the US, Japan and the European Union.[19] The fact that FCVs constitute the only clean vehicle niche wherein China is not leading in terms of absolute production and sales might suggest that the Chinese government does not regard FCVs as a viable solution to the energy security threats surrounding PEVs.

However, recent changes in policy suggest otherwise. In 2016 the Chinese government published a series of roadmaps and bluebooks outlining China's strategy and targets for FCVs until 2050.[20] In one of these roadmaps, China has set the goal to produce one million FCVs by 2030, which is the most ambitious FCV target to date and it is said that the government has raised its budget for hydrogen development to two billion euro annually, making it by far the highest in the world.[21] Ever since, the central and local governments, vehicle manufacturers and research institutes have displayed an increasing interest in the development of FCVs and hydrogen. Many pilots, R&D programs, commercial activities have been launched as a result. This all suggests unequivocally that FCVs have caught the attention of the Chinese government.[22]

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lithium-ion batteries: from resource depletion to environmental performance indicators', *Journal of Cleaner Production* 108 (2015) 354-362, 356; and: Sverdrup, 'Modelling global extraction, supply, price and depletion of the extractable geological resources within the LITHIUM model', 126.

[17] FCVs are also known as 'hydrogen vehicles.'

[18] H2 Platform, 'Waterstof voor dummies' (version 27 January 2017) https://opwegmetwaterstof.nl/2017/01/20/waterstof-voor-dummies/, 20 December 2018.

[19] *International Energy Agency*, 'Global EV Outlook 2018', 20, 111; and: Jingzheng Ren, Suzhao Gao, Shiyu Tan and Lichun Dong, 'Hydrogen economy in China: Strengths-weaknesses-opportunities-threats analysis and strategies prioritization', *Renewable and Sustainable Energy Reviews* 41 (2015) 1230-1243, 1234.

[20] Michaela Kendall, 'Fuel cell development for New Energy Vehicles (NEVs) and clean air in China', *Progress in Natural Science: Materials International* 28 (2018) 113-120, 117.

[21] Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 28 October 2016, 3.2; and: Bart Biebuyck, 'Interview with Bart Biebuyck, executive director of the Fuel Cells and Hydrogen Joint Undertaking conducted by Merijn Drenth', 16 March 2018.

[22] Pang Xiangmin, 'IPHE Country Update October 2016: China', *International Partnership for Hydrogen and Fuel Cells in the Economy'*, October 2016; and: Pan Xiangmin, 'IPHE Country Update March 2017: China', *International Partnership for Hydrogen and Fuel Cells in the Economy'*, March 2017; and: Pang Xiangmin, 'IPHE Country Update November 2017: China', *International Partnership for Hydrogen and Fuel Cells in the Economy'*, November 2017; and: Zhang Cunman, 'IPHE Country Update May 2018: China', *International Partnership for Hydrogen and Fuel Cells in the Economy'*, May 2018.

Combined, the sheer importance of energy security to the Chinese leadership, the fact that PEVs have come to exhibit many of the potential threats that made ICEVs problematic in the first place and the recent upsurge in Chinese FCV policies and pilots make it essential to reconsider the widely accepted hypothesis that PEVs enhance China's (sense of) energy security and examine whether FCVs are now considered to be a more viable solution to oil imports than PEVs. This is exactly what this research will do.

Thus far, no studies have covered this subject, which makes this topic unique and worth exploring. What makes this research particularly important is that China has been leading the transition from ICEVs to PEVs and -as the world's largest car producer and market- has a defining impact on the direction that future transport technology will take. Currently, the odds seem to favor PEVs, as they vastly outnumber FCVs and are less costly. However, if China's increasing interest in FCVs is the result of the government's conviction that these vehicles are better equipped to improve China's energy security than PEVs, it is quite possible that FCVs will come to play a very important – if not dominant – role in the transport sector of China and perhaps even the world. After all, both PEVs and FCVs are heavily dependent on government support and if the Chinese government were to increase its commitment to FCVs at the expense of PEVs, it might mean the downfall of the latter and the rise of the former.

This research will therefore aim to answer the following research question:

- *To what extent have PEVs been replaced by FCVs as the Chinese government's most promising energy security solution to China's increasing dependency on imported oil since 2016?*

Given that this research revolves around the Chinese government's perception of energy security, it is essential to explain in more detail what *energy security* exactly entails and in what manner the concept will be used throughout this research. Previously, the most basic definition was already given: an "uninterrupted availability of energy sources at an affordable price."[23] However, the concept has absorbed new elements and dimensions since its inception in the late 1980s and, as a result, various new definitions of the concept energy security have emerged. Important for this research are three particular additions to the concept.

The first addition is the defining of energy security as a matter of *perception*. After all, this thesis is not aimed at researching whether FCVs are actually in a better position to guarantee energy security than PEVs. Instead, it aims to examine whether the Chinese government perceives it as such. In this context, Leung et al. provide a definition of energy security that is relevant for this research. Drawing

[23] Yergin, 'Energy Security in the 1990s', 111; and: Bielecki, 'Energy security', 237; and: International Energy Agency, 'Energy Security' (Version 13 December 2018) https://www.iea.org/topics/energysecurity/ 13 December 2018.

upon the *securitization theory*, they argue that 'a policy problem becomes a *security* issue if an agent manages to cast it as an "existential threat" or a "supreme priority" which requires treatment and intervention by extraordinary means' - an energy policy problem becomes an energy security issue if it is presented and perceived as affecting the stability (and in critical situations, the survival) of a nation, the "functioning" and "continuity" of the economy or the realization of major national values and objectives.'[24] In the case of China, oil import dependency is clearly regarded by the government as the primary energy security issue, whereas PEVs and FCVs are seen as the treatment and intervention required to tackle it.

A second important development has been the addition of various dimensions. Initially, energy security focused primarily on economic and technological dimensions, but during the last two decades, new dimensions, such as diversification, environmental protection, foreign policy, human security, import dependency, international relations and national security, have been added to the concept.[25] As will become evident throughout this thesis, foreign policy, international relations and national security dimensions have a major impact on how the Chinese government perceives energy security (risks) and how it shapes energy policies and responses. China's turbulent history, resource scarcity, its appetite for energy and traumatic experience with oil has led Goldthau to argue that the Chinese leadership defines 'energy security as "security of supply"; and [that] they regard energy as a "hard security" issue.'[26] Leung et al. too have argued that China -other than most countries- equates energy security with 'national security' and that the government regards energy security risks mostly as threats from outside of China, typically originating from other nations.[27]

A final addition is the inclusion of rare metals as an energy security dimension. As was mentioned, key components of batteries have largely been ignored in the energy security literature, but not entirely. With the emergence of renewables, rare metals have been integrated in the energy security literature to some extent but so far, academics have not studied their impact on the energy security potential of PEVs as a solution to oil security risks, let alone in the context of China.[28]

Having established energy security as the overarching concept of this thesis, it is now necessary to map out how this research will proceed. First, an introductory chapter will establish the dominant role

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[24] Leung et al., 'Securitization of energy supply chains in China', 317.
[25] Marilyn A. Brown and Michael Dworkin, 'The environmental dimension of energy security', in Benjamin K. Sivacool (ed.), *The Routledge Handbook of Energy Security* (Abingdon 2011) 176-190; and: Gal Luft, Anne Korin and Eshita Gupta, 'Energy security and climate change: A tenuous link', in Benjamin K. Sivacool (ed.), *The Routledge Handbook of Energy Security* (Abingdon 2011) 455; and: Martin J. Pasqualetti, 'The competing dimensions of energy security', in Benjamin K. Sivacool (ed.), *The Routledge Handbook of Energy Security* (Abingdon 2011) 275-290; and: Lixia Yao and Youngho Chang, 'Energy security in China: A quantitative analysis and policy implications', *Energy Policy* 67 (2014) 595-604, 596.
[26] Andreas Goldthau, 'The public policy dimension of energy security', in Benjamin K. Sivacool (ed.), *The Routledge Handbook of Energy Security* (Abingdon 2011) 129-145, 129.
[27] Leung et al., 'Securitization of energy supply chains in China', 324.
[28] M.Z. Jacobson and M.A. Delucchi, 'A path to sustainable energy by 2030', *Scientific American* 301 (2009) 5, 58-65; and Karen Smith Stegen, 'Heavy rare earths, permanent magnets, and renewable energies: An imminent crisis', *Energy Policy* 79 (2015) 1-8.

that oil plays in the Chinese government's perception of energy security since the nineteenth century. This is necessary because it illustrates how deep its concern for oil is rooted, how desperate the government is to reduce its dependency on imported oil and why this sits at the core of China's decision to deploy PEVs. It will answer the following sub-question:

- *What historical events and experiences (from 1839 until the present) have caused the central government of the PRC to regard oil as China's most important energy security challenge?*

The second chapter will draw upon the first and explain how energy security is the most dominant factor in the Chinese government's decision to develop and deploy PEVs. On the basis of primary sources (a Sino-Dutch round table, the 12th and 13th Five-Year Plans, Made in China 2025 and other policy documents by the State Council and relevant ministries) and various secondary sources, it will examine to what extent PEVs have been regarded by the government as the most promising solution to China's oil import dependency between 1995 and 2016. The following sub-question will be addressed:

- *To what extent has the Chinese government regarded PEVs as the most promising strategy to reduce China's oil import dependency between 1995 and 2016?*

The function of the third chapter is to examine whether the LIB supply chain and various (technical) aspects of PEVs display liabilities that resemble the energy security risks surrounding oil, which caused China to develop PEVs in the first place. It will focus largely on the supply chain risks of LIB components and examine whether PEVs possess traits that would make them undesirable in the eyes of the Chinese government, by taking into account their outlook on what constitutes energy security. Secondary sources and news articles form the primary basis of this third chapter. These sources largely focus on the supply chains of rare materials (lithium and cobalt), without taking into account the dimension of energy security. Therefore, an additional function of this chapter is to integrate and synergize these sources into an energy security context. The following sub-question will be addressed:

- *What dimensions of the LIB supply chain and what (technical) aspects of PEVs constitute a potential energy security risk to the Chinese government?*

Having laid out the energy security risks of PEVs, the final chapter aims to demonstrate whether the Chinese government's sudden interest in FCVs is tied to its realization that PEVs are indeed a less reliable and less promising solution to China's oil dilemma than was previously thought. This chapter will mostly focus on PEV and FCV policies from 2016 that might demonstrate if this year formed an important turning point and whether the Chinese government increased its commitment towards FCVs while reducing its investments in PEVs. Additionally, it will also examine the nature of various FCV pilots and some of the technical aspects of FCVs that might reveal something about their energy security potential. The main sources of this chapter are the Fuel Cell Vehicle Technology Roadmap[29] and the two-yearly briefings that China publishes for the International Partnership for Hydrogen and Fuel Cells in the Economy.[30] Also used are various news articles, the previously mentioned Sin-Dutch round table, secondary literature and interviews with two hydrogen experts: Dick de Jongste, CEO of Teesing[31] and Bart Biebuyck, director of the Fuel Cells and Hydrogen Joint Undertaking.[32]

With the findings of the previous chapters in mind, the conclusions of the final chapter are able to provide a satisfactory answer to the main research question:

- *To what extent have PEVs been replaced by FCVs as the Chinese government's most promising energy security solution to China's increasing dependency on imported oil since 2016?*

[29] The Fuel Cell Vehicle Technology Roadmap is Published by the Society of Automotive Engineers of China and functions is considered to be China's preeminent guiding policy in the field of FCVs.
[30] The International Partnership for Hydrogen and Fuel Cells in the Economy is an international organization whose members are countries that are active in the field of hydrogen and FCVs. The purpose of this partnership is to exchange information about policies, pilots, research and the overall progress that hydrogen and FCVs have made.
[31] Teesing is a company that is active in the FCV and hydrogen sector and with comprehensive experience in China.
[32] The Fuel Cells and Hydrogen Joint Undertaking is a public-private partnership that is made up of the 'European Commission, [the] fuel cell and hydrogen industries represented by Hydrogen Europe and the research community represented by Hydrogen Europe Research'; Fuel Cells and Hydrogen Joint Undertaking, 'Who we are' (version 7 January 2019) https://www.fch.europa.eu/page/who-we-are 7 January 2019.

1. China's historical relationship with oil

This chapter will provide an account of China's historical relationship with oil (1839 – present) and how this became the Chinese government's foremost energy security concern. This chapter aims to demonstrate how its obsession over oil security forms the foundation of China's ambitious drive to deploy plug-in electric vehicles (PEVs).

1.1 Humiliation and self-determination

In order to fully grasp the obsession of the Chinese leadership with energy security and oil security in particular, it is necessary to go back all the way to the nineteenth century, when China's so-called *Century of Humiliation* (1839-1949) began after the British Empire declared war on the Qing Dynasty. The First Opium War (1839-1842) was to a significant degree the result of the British disagreeing -to put it mildly- with China's isolationist policies that had been in place since the early Ming Dynasty (1368-1644). After winning the war, the British ended this tradition and initiated a period wherein China was colonized and exploited by the Western powers and Japan.[33]

That the imposed end of isolation and autarky heralded an era of exploitation, humiliation and turmoil is the first important factor that helps to explain China's view on energy and energy security. It is interconnected with a second important factor, one that developed as a result of foreign domination and had a profound effect on China's return to isolationism after it became independent again in 1949: nationalism. Arising in the late 19th and early 20th centuries, Chinese nationalism was heavily influenced by the ongoing exploitation and it were in fact nationalists (among them the communists led by Mao Zedong) that invented and popularized the phrase "Century of Humiliation" and made it an inseparable component of Chinese identity.[34] This narrative resonated among China's inhabitants and leaders to such an extent that Mao Zedong personally marked the founding of the People's Republic as the end of the Century of Humiliation in his opening speech during the First Plenary Session in 1949.[35] Given that this period of national humiliation had started when China was

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[33] Alison Adcock Kaufman, 'The "Century of Humiliation," Then and Now: Chinese Perceptions of the International Order', *Pacific Focus* 25 (2010) 1-33, 1-2, 5.
[34] Kaufman, 'The "Century of Humiliation," Then and Now',2-3.
[35] Mao Zedong, 'The Chinese People Have Stood Up! 1949: Opening address by Mao Zedong, Chairman of the Chinese Communist Party at the First Plenary Session of the Chinese People's Political Consultative Conference', *USC US-China Institute*, (version 21 September 1949) https://china.usc.edu/Mao-declares-founding-of-peoples-republic-of-china-chinese-people-have-stood-up 11 January 2019.

forced to open up itself up to foreign trade and influences, a return to isolationism, self-reliance and a deep suspicion of other nations was perceived as vital if China wanted to maintain its newly regained sovereignty.[36]

However, upholding complete economic autarky was impossible in the modern era. After three decades of internal turmoil and gripping poverty, the communist leadership realized that it had to open up its markets to the world if it wanted to make China resilient in a rapidly modernizing world led by two nuclear superpowers. Deng Xiaoping's decision to reform China's economy in 1978 paid off and effectively transformed China into a formidable powerhouse that is nowadays no longer at the mercy of geopolitical currents, but capable of shaping the new world order itself. Nevertheless, despite these developments, the doctrine of self-reliance is still very much alive among the Chinese leadership and maintains a significant impact on China's policies.[37] China might nowadays be the world's workshop, but its government has always been reluctant to fully assimilate itself in the international community. China actively tries to limit the influx of foreign goods into its own markets through steep import taxes, unfair practices and protectionist policies that favor Chinese companies and products over foreign ones.[38]

Thus, self-reliance and isolationism are still high on the agenda, but have to coexist alongside economic and industrial ambitions that the Chinese government regards as equally vital for the security, survival and success of China and which demand it to be firmly established within the global economy. As a result, China's autarkic ambitions have adopted a less holistic and more strategic character, focusing on areas that the government regards as absolutely crucial.[39] As the cornerstone for China's economic, industrial and military prowess, energy -and thus its security- is regarded by Chinese policymakers as the most vital element of a self-reliant and sovereign China.[40]

1.2 The strategic importance of oil

How then, did oil become the nucleus of the government's energy security agenda? After all, coal -not oil- dominates China's energy mix with a 60% share in 2017. It is responsible for powering roughly 70 percent of China's electricity grid, making it an indispensable resource for Chinese society that is

[36] Jackson S. Woods and Bruce J. Dickson, 'Victims and Patriots: Disaggregating Nationalism in Urban China', *Journal of Contemporary China* 26 (2017) 104, 167-182, 171-172.
[37] Gabriel Wildau, 'China's Xi Jinping revives Maoist call for "self-reliance"', *Financial Times* (version 12 November 2018) https://www.ft.com/content/63430718-e3cb-11e8-a6e5-792428919cee, 31 December 2018; and: Clem Tisdell, 'China's Goal of Combining Economic Self-Reliance with its Development : Changing Perspectives and Challenges', *Social Economics, Policy and Development* 54 (2013) 1-16, 12.
[38] Fayen Wong, 'Rise of protectionism in China a threat to commodities imports', *Reuters* (version 13 November 2014) https://www.reuters.com/article/china-trade-commodities-protectionism-idUSL3N0T12MG20141113 31 December 2018; and: Dexter Roberts, 'China's New Protectionism', *Bloomberg*, 28 October 2011; and: Financial Times, 'China's protectionism comes home to roost' (version 3 January 2018) https://www.bloomberg.com/news/articles/2011-10-27/chinas-new-protectionism 31 December 2018.
[39] State Council of the People's Republic of China, 'Made in China 2025', 7 July 2015, preface.
[40] Ole Odgaard and Jørgen Delman, 'China's energy security and its challenges towards 2035', *Energy Policy* 71 (2014) 107-117, 115-116; and: Nadège Rolland, 'China's "Belt and Road Initiative": Underwhelming or Game-Changer?', *The Washington Quarterly,* 40 (2017) 1, 127-142, 133.

perhaps even more important than oil.[41] However, coal, but also hydropower and natural gas, are perceived less as energy security issues and more as socio-economic challenges.[42] This is because China is the largest coal producer in the world and capable of powering most of its enormous electricity grid by domestically produced coal.[43]

It is true that coal has become increasingly problematic in the eyes of the Chinese population and constitutes a difficult issue for the Chinese government.[44] However, coal's primary function in China is to produce thermal power for the electricity grid and electricity can be generated by a multitude of power sources.[45] This is a second reason why most issues concerning energy sources are not seen as a security threat by the government. Natural gas, hydro, nuclear, solar and wind power are all predominantly turned into electricity and can be replaced by one another. With the exception of natural gas, they can also be produced domestically and infinitely, which drastically reduces coal and other energy sources as security hazards for the Chinese government, that, in the words of Leung et al., 'remains rigid with equating "security" with "national security" [meaning that] risks to national energy security are something that affects the nation as a whole and is likely to originate externally, from other nations.'[46] Therefore, replacing the increasingly problematic coal plants with alternatives is perhaps socio-economically challenging for China, but not necessarily perceived by its government as a security threat.

When assessing the supply chain and function of oil, it becomes obvious why oil is not perceived as a socio-economic issue. Oil has been the primary power source of the world's motorized transport systems for well over a century and was utterly irreplaceable until recently. Even though PEVs are gradually replacing regular cars, some very crucial modes of transport -aviation, shipping, military transport and missiles- will only be able to run on petrol fuels for decades to come.[47] In addition, oil is a scarce resource that is geographically dispersed and whose availability is becoming increasingly limited.[48] However, these problems are universal and by no means limited to China. The next section will therefore delve into China's historical relationship with oil from the early days of the People's Republic until the present and explain for what reason oil security in China has historically

[41] Emily Feng, 'China's annual coal consumption rises for the first time in 3 years', *Financial Times* (version 28 February 2018) https://www.ft.com/content/5d351276-1c48-11e8-aaca-4574d7dabfb6 31 December 2018.
[42] Hydropower and natural gas are China's other important energy sources.
[43] U.S. Energy Information Administration, 'China produces and consumes almost as much coal as the rest of the world combined' (version 14 May 2014) https://www.eia.gov/todayinenergy/detail.php?id=16271# 20 December 2018.
[44] Many coal plants in the east have been closed down in order to reduce the highly problematic air pollution that plagues China's largest cities; Edward Wong, 'Coal Burning Causes the Most Air Pollution Deaths in China, Study Finds', *The New York Times* (version 17 August 2016) https://www.eia.gov/todayinenergy/detail.php?id=16271 31 December 2018.
[45] Leung et al., 'Securitization of energy supply chains in China', 324.
[46] Ibidem, 319, 324.
[47] Ibidem, 324.
[48] Yergin, *The* Quest, 229-230, 241-243.

been so high up on the agenda. By doing so, this chapter will establish the hypothesis that insecurities surrounding oil are the primary driver for China's aggressive PEV adoption policies.

1.3 China's oil trauma

China's first encounter with oil was in 1863, when the first imports arrived in its ports.[49] This was before the era of the automobile when oil was destined for lamps only. Both oil and oil lamps were introduced in China by Western companies and illustrate how the once isolated Middle Kingdom was now being flooded with the products of foreign traders who were all too eager to sell their goods to China's vast population. When automobiles and airplanes did enter China and played indispensable roles in the Chinese Civil War (1927-1950) and the Sino-Japanese War (1937-1945), oil was still being provided for by Western oil companies, which now regarded China as an important market.[50] The majority of scientific assessments had concluded that China was poor in oil and thus Chinese freedom fighters had no choice but to depend on the patronage of the great powers.[51]

Immediately after the People's Republic had been established in 1949, the Chinese leadership was confronted with the downsides of being fully dependent on imported oil. The US and its allies limited oil shipments to China before halting them altogether after China chose to support North Korea in the Korean War (1950-1953). This severely undermined its military capabilities and left China dependent on oil imports from the Soviet Union.[52] This lifeline too was cut off when the two countries entered a period of fierce rivalry (1956-1966) due to their disputes over communist ideology. This led the Soviet Union to withdraw all of its petroleum experts and machinery from China.[53]

According to Yergin, the Chinese leadership interpreted these developments as Soviet-American aggression against China's newly acquired independence. Subsequently, oil established itself as an important element of Chinese sovereignty. Self-reliance in oil became a key target of the first Five-Year Plan and was stressed frequently by China's leaders.[54] This included Mao Zedong and Zhu De, Commander-in-Chief of the People's Liberation Army, who mostly linked the importance of oil to the capabilities of China's armed forces. This made sense, as oil made up only a tiny fraction of China's energy mix in the 1950s and was mostly used by the military.[55] Following this, the Chinese embarked on desperate exploration missions, hoping to discover oilfields that could increase the meagre 3.500 barrels that China produced on a daily basis in 1952.[56]

[49] Kardon, 'Oil for the Lamps of China', 318.
[50] Ibidem.
[51] Ibidem.
[52] Yergin, *The Quest*, 197.
[53] Ibidem, 197-198.
[54] Ibidem, 197.
[55] Leung et al., 'Securitization of Energy Supply Chains in China', 318.
[56] Yergin, *The Quest*, 196.

After years of fruitless endeavors, there finally was a major breakthrough when a small drilling team discovered the Daqing oilfield in 1959. Daqing contained some sixteen billion barrels of oil and became a symbol for a resilient, independent and communist China.[57] For Mao Zedong, the discovery was also the undeniable proof of foreign treachery. He and other Chinese leaders had always rejected the scientific consensus of Western academics that China was poor in oil. Now they were convinced that it had been a Western conspiracy to keep China weak and dependent on foreign oil.[58] In the wake of Daqing, more large oilfields were found and the Chinese leadership vowed to never become dependent on imported oil again. By 1963, China had become a net exporter of oil.[59]

1.4 A return to oil imports

China upheld its promise for thirty years, but in 1993 domestic oil production was simply incapable of keeping up with China's economic progress. Once more, it was forced to look beyond its borders for oil and this time it seemed impossible that it could ever return to a position of self-reliance. China's economy and industry were simply growing too fast and Chinese experts were very skeptical about the prospects of future onshore oilfield discoveries.[60] A return to oil imports came as a shock to Chinese policymakers. They thought of it as 'a disaster'[61] and 'an abject failure of self-reliance.'[62]

The subsequent responses leave little doubt that importing oil was still regarded by the Chinese government as a major security issue. Almost immediately, Chinese scientific publications about oil and energy security surged.[63] In addition, the central government launched massive modernization programs to transform the Chinese oil industry from a centrally planned and inward looking system, to one that was based on companies and rooted in the global marketplace.[64] As a result of this 'Go-Out' strategy, the responsibility of oil (acquisition) was transferred from the archaic petroleum and chemical industry ministries to the more dynamic national oil companies (NOCs). Like their predecessors, These NOCs were firmly integrated within the Chinese government, but operated internationally like any other oil multinational and were thus better equipped to get access to foreign oil.[65] NOCs started to acquire numerous oilfields and refineries worldwide to satisfy China's rapidly growing oil demand. By 2003, the import share had already climbed to 39 percent.[66]

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57 Leung et al., 'Securitization of Energy Supplies in China', 318; and: Yergin, *The Quest*, 197-199.
58 Yergin, *The* Quest, 197, 199.
59 Yergin, *The Quest*, 198; and Kardon, 'Oil for the Lamps of China', 318.
60 Kardon, 'Oil for the Lamps of China', 319.
61 Yergin, *The Quest*, 203.
62 Kardon, Oil for the Lamps of China', 319; and Leung et al., 'Securitization of Energy Supplies in China', 322; and Yergin, *The Quest*, 203,
63 Leung et al., 'Securitization of Energy Supplies in China', 318.
64 Hai-Ying Zhang, Qiang Ji and Ying Fan, 'An evaluation framework for oil import security based on the supply chain with a case study focused on China', *Energy Economics* 38 (2013) 87-95, 92.
65 The CEOs of the largest NOCs hold vice-ministerial government rank; Yergin, *The Quest*, 202-208; and: Leung et al., 319-320.
66 Zhang et al., 'An evaluation framework for oil import security based on the supply chain with a case study focused on China', 92.

In the 10th Five-Year Plan (2001-2005), energy security was for the first time explicitly mentioned as a top priority and mostly concerned the safeguarding of oil imports, the construction of strategic petroleum reserve systems, oceanic exploration and the diversification of oil supplies.[67] The latter strategy materialized in massive pipeline and infrastructure projects that connected China to major oil producers like Iran, Russia and Kazakhstan or strategic seaports in Myanmar and Pakistan. These projects would later be absorbed into the Belt and Road Initiative, China's largest development strategy wherein oil security plays a crucial role.[68]

1.5 Threats to China's oil supply chain

As a 'latecomer'[69] to the global oil market and in a world where oil is becoming increasingly scarce, China's NOC's have often had to resort to deep water exploration and the acquisition of oilfields in geographically challenging or politically instable regions.[70] This has frequently led to very problematic situations for China and re-established one particular country as a major energy security threat to China: the US.

US military interventions in Iraq (2003) and Libya (2011) obliterated billions of euros worth of oil contracts and caused serious harm to China's economy.[71] Given the dismal relations that the US has with Iran, Russia and Venezuela (three of China's major oil suppliers), the Chinese government has reason to fear for more blows to its oil supply chain in the form of multilateral sanctions, blockades or even war. In addition, many of China's major oil suppliers are themselves unstable or positioned in unstable regions (the Middle East, Angola and Venezuela).[72] However, China's biggest worry regarding the US is that the latter is prepared to wage war over oil itself. The Chinese government is convinced that this was the US's ultimate motive for invading Iraq. According to Yergin, this further strengthened the Chinese government's resolve that energy security should be perceived as a primary policy focus.[73]

There is something to be said about these worries. China is currently the world's largest importer of oil and as long as its economy is still growing, its appetite for oil will too.[74] The fact that

[67] Xueliang Yuan and Jian Zuo, 'Transition to low carbon energy policies in China: from the Five-Year Plan Perspective', *Energy Policy* 39 (2011) 3855-3859, 3856.
[68] Kardon, 'Oil for the Lamps of China', 319; and: Yergin, *The Quest*, 205.
[69] Meaning that companies from Western or OPEC countries have snatched up most major deposits and possess superior up- and downstream technologies.
[70] Kardon, 'Oil for the Lamps of China', 319.
[71] Sevilla, 'The 'Arab Spring' and South China Sea Tensions', 97.
[72] Ed Crooks, 'The global impact of China's oil imports', *Financial Times* (version 25 September 2017) https://www.ft.com/content/e7d52260-a1e4-11e7-b797-b61809486fe2 31 December 2018.
[73] Yergin, *The Quest*, 211.
[74] In 2015, 60 percent of China's oil had to be imported, meaning that 18,6 percent of worldwide oil imports are destined for Chinese use; Yuhua Zheng, 'Evaluating China's Oil Security and Overseas Oil Investment', *American Journal of Industrial and Business Management* 7 (2017) 8, 959-972, 959; and: Daniel Workman, 'Crude Oil Imports by Country', *World's Top Exports* (version 26 December 2018) http://www.worldstopexports.com/crude-oil-imports-by-country/ 31 December 2018.

China is destined to become the largest oil consumer in a world where oil is becoming increasingly scarce is highly problematic for the government. In part, because it sees a reliable and constant flow of oil as a prerequisite for China's economic growth which, in turn, is a prerequisite for the country's internal stability.[75] The world knows this too and is equally aware of the fact that the vast majority of China's imported oil has to be shipped.[76] In fact, more than half of its oil shipments go through the Strait of Hormuz and as much as 80 percent passes the Strait of Malacca and the South China Sea. This makes China's oil supply chain particularly vulnerable to the US, whose navy maintains a large presence in all of these strategic chokepoints.[77]

Moreover, chances that the US will utilize its naval superiority to cut off China from its much needed oil supplies have certainly not been declining. Under the Obama administration, the nucleus of American geopolitics has shifted from the Middle East to the Asia-Pacific and it has become unmistakably clear that this is a response to China's rise as a world power.[78] As a result, Sino-American tensions have been slowly rising and became first apparent in the South China Sea. These waters, that China claims as its own, are said to contain somewhere between 28 and 213 billion barrels worth of oil reserves, which partially explains why China has been doubling down on its claims in recent years. It would not be unthinkable for Chinese policymakers to assume that US opposition to China's claims might have something to do with this.[79]

Aside from this military build-up on China's southern flank, its entire seaboard has been encircled by staunch US allies and territories that host significant amounts of US military facilities for decades (Guam, Japan, Singapore South Korea and Taiwan). Moreover, recent developments indicated that the US aims to strengthen its presence to keep China at bay. For example, president Trump's rapprochement with North Korea is interpreted by some as an American strategy to pull North Korea away from China's sphere of influence, while the US's recent announcement to withdraw from the Intermediate-Range Nuclear Forces Treaty partially reveals an American desire to throw off the shackles of arms control and respond to Chinese progress in the field of ballistic missiles.[80]

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[75] David C. Gompert, *Sea Power and American Interests in the Western Pacific* (Santa Monica 2013) 86-87, 100.
[76] Owen Daniels and Chris Brown, 'China's Energy Security Achilles Heel: Middle Eastern Oil', *The Diplomat (version* 8 September 2015) https://thediplomat.com/2015/09/chinas-energy-security-achilles-heel-middle-eastern-oil/ 31 December 2018; and: Gompert, *Sea Power and American Interests in the Western Pacific*, 72, 86.
[77] Odgaard and Delman, 'China's energy security and its challenges towards 2035', 113.
[78] Hillary Clinton, 'America's Pacific Century', *Foreign Policy*, 11 October 2011; and: Australian Broadcasting Corporation, 'U.S. President Barack Obama addresses the Australian Parliament 17-11-2011', uploaded on YouTube on 17 November 2011, https://www.youtube.com/watch?v=8_hSqLEtX_Y.
[79] Randy Fabi and Chen Aizhu, 'Analysis: China unveils oil offensive in South China Sea squabble', *Reuters* (version 1 August 2012) https://www.reuters.com/article/us-southchinasea-china/analysis-china-unveils-oil-offensive-in-south-china-sea-squabble-idUSBRE8701LM20120801 31 December 2018.
[80] Nyshka Chandran and Weizhen Tan, 'China could come away a big winner from a US-North Korea peace deal', *CNBC* (version 11 June 2018) https://www.cnbc.com/2018/06/11/us-north-korea-summit-chinas-interests.html 31 December 2018; and: Mercy A. Kuo, 'US Withdrawal from INF Treaty: Impact on China', *The*

Whether the growing Sino-American tensions will eventually lead to American naval blockades or war is impossible to say. However, this and other developments that were mentioned, explain why China's increasing dependency on imported oil is regarded as a security threat by the Chinese government. Nevertheless, self-reliance in oil has become impossible and even though China has launched ambitious projects to redirect its oil routes and sources away from vulnerable sea-lanes, it is simply not enough, as most of China's imported oil is still being shipped through these hazardous chokepoints.

1.6 The rise of a middle class

What is also different this time, is that oil is no longer predominantly destined for military use. In fact, the primary contributor to China's surging oil consumption is a growing middle class with an appetite for cars. This is the foremost reason why China's annual vehicle sales grew from 1,9 million in 2000 to 29 million in 2017. Thus, China transformed from an insignificant market into the world's largest vehicle market by far.[81] That an increasing number of Chinese people has been lifted out of poverty and can now afford to buy cars can generally be regarded as positive. However, it has also made China's economy heavily dependent on car-driving commuters. Severe disruptions in oil would therefore not only be detrimental to the capabilities of the armed forces but they are guaranteed to bring China's economic growth to a grinding halt. This can have enormous consequences for the internal stability and authority of the communist regime.

This chapter therefore concludes that China's dependency on imported oil is regarded by the government as China's most daunting energy security concern. Due to the growing demand for oil and insufficient domestic reserves, moving away from an oil-based economy is the only real solution to the government's insecurities. As will become clear in the next chapter, it is mainly due to this reason that the government has been stimulating the development, production, use and sales of PEVs since the mid-1990s.

Diplomat (version 6 November 2018) https://thediplomat.com/2018/11/us-withdrawal-from-inf-treaty-impact-on-china/ 31 December 2018.

[81] Yergin, *The Quest*, 219; and Organisation Internationale des Constructeurs d'Automobiles, 'Provisional registrations or sales of new vehicles - all types' (version 28 december 2018) http://www.oica.net/wp-content/uploads/Sales-all-vehicles-2017.pdf (28 December 2018).

2. Plug-in electric vehicles in China

The previous chapter demonstrated how oil imports are the foremost energy security concern of the Chinese government and that China's rapidly growing vehicle stock is currently the major contributor to the country's surging demand for oil. This chapter will examine to what extent the Chinese government has regarded plug-in electric vehicles (PEVs) as the most promising strategy to alleviate China's oil problem since the mid-1990s and until 2016.

2.1 Environmental and economic considerations

Environmental concerns are often cited as the most important drivers behind a country's decision to deploy PEVs. This is also the impression of most scholars, who tend to view China's pursuit of PEVs as response to human-induced climate change and air pollution.[82] Others point out economic considerations as a primary or equally important driver.[83] Thus, before we move on, it is necessary to explain why energy security plays a more prominent role in the decision for PEVs than these other factors.

This does not mean that other factors have little or no impact. Environmental concerns were prominent themes in the three latest Five-Year Plans (FYPs, 2006-2020) and have been backed by strict regulations.[84] This has frequently led to government crackdowns on factories and plants throughout the country.[85] Given that an estimated 1,6 million people die annually in China as a result

[82] Bohnsack, 'Local niches and firm responses in sustainability transitions', 20; and: Hao et al., China's traction battery technology roadmap, 355; and: Wenhui Tian and Pascal da Costa, 'A Prospective Analysis of CO2 Emissions for Electric Vehicles and the Energy Sectors in China, France and the US (2010-2050)' in: Pascal da Costa and Danielle Attias (ed.), *Towards a Sustainable Economy: Paradoxes and Trends in Energy and Transportation* (Cham; 2018) 29-50, 29-30.
[83] Bohnsack, 'Local niches and firm responses in sustainability transitions', 20; and: Wang et al., 'China's electric car surge', 486.
[84] The Five-Year Plans are China's paramount policy guides and determine the overall course of China for a period of five years; S.R., 'Why China's five-year plans are so important', *The Economist* (version 26 October 2015) https://www.economist.com/the-economist-explains/2015/10/26/why-chinas-five-year-plans-are-so-important 31 December 2018; and: ZhongXiang Zhang, 'Policies and Measures to Transform China into a Low-carbon Economy', in: Ligang Song, Ross Garnaut, Cai Fang and Lauren Johnston (ed.), *China's New Sources of Economic Growth: Vol. 1*, (Canberra 2016) 397-418, 400.
[85] Meng Meng and Aizhu Chen, 'Chinese chemical producers curb output on new round of inspections', *Reuters* (version 7 May 2018) https://www.reuters.com/article/us-china-pollution-chemicals/chinese-chemical-producers-curb-output-on-new-round-of-inspections-idUSKBN1I80UH 31 December 2018.

of severe air pollution, it is absolutely reasonable to assume that these factors play an important role in the decision-making of the Chinese leadership as well.[86]

Nevertheless, despite the focus of the most recent FYPs on climate change and other environmental concerns, the aggressive measures of the Chinese government to stimulate the growth of PEVs (which will be discussed below), conflicts with the modest decline of coal usage in the energy mix.[87] As a result, the well-to-wheel greenhouse gas (GHG) emissions of battery-electric vehicles (BEVs[88]) in China are 50% higher than those of petrol-fueled cars and have been said to increase air pollution and smog levels rather than reducing them.[89] This sharply contrasts the situation in most other countries. For example, well-to-wheel GHG emissions of BEVs in the Netherlands are at least 30% less than those of internal combustion engine vehicles (ICEVs), whereas in Norway they are almost zero due the fact that 96% of Norway's electricity comes from hydropower.[90]

Moreover, renewable energy systems as a solution to environmental concerns have only been acknowledged as such in China in 2005, when Congress passed the Renewable Energy Law.[91] In contrast, the government's interest in PEVs dates back to 1995. In that year, the 9th FYP (1996-2000) was published and highlighted BEVs as one of the 'National Key Science & Technology Industrialization Projects.' This led to the first pilots and research and development (R&D) programs that concerned PEVs.[92] PEV R&D emerged in the direct aftermath of China's return to a dependency on oil imports and around the same time when energy security emerged as a primary focus of Chinese academics and policymakers. This strongly suggests that PEVs were framed as an energy security strategy from the onset. Not as a solution to environmental problems. This is backed by the fact that PEV policies have virtually never been a responsibility of the Ministry of Environmental Protection (which did not exist prior to 2008) or its successor, the Ministry of Ecology and Environment. Instead, virtually all PEV-related legislation has been published by the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC) and the Ministry of

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[86] Jeff Kearns, Hannah Dormido and Alyssa McDonald, 'China's War on Pollution Will Change the World', *Bloomberg* (version 9 March 2018) https://www.bloomberg.com/graphics/2018-china-pollution/ 31 December 2018.
[87] Tian and da Costa, 'A Prospective Analysis of CO2 Emissions for Electric Vehicles and the Energy Sectors in China, France and the US', 40.
[88] Battery electric vehicles are one of the two vehicle types that constitute PEVs. In comparison to plug-in hybrid electric vehicles –that contain a battery as well as an internal combustion engine– BEVs are fully electric.
[89] Qinyu Qiao, Fuquan Zhao, Zongwei Liu, Shuhua Jiang and Han Hao, 'Cradle-to-gate greenhouse gas emissions of battery electric and internal combustion engine vehicles in China', *Applied Energy* 204 (2017) 1399-1411, 1409; and: Jake Spring, 'In coal-powered China, electric car surge fuels fear of worsening smog', *Reuters* (version 27 January 2016) https://www.reuters.com/article/us-china-pollution-autos-idUSKCN0V51BH 31 December 2018.
[90] R.P. Verbeek, M. Bolech, R.N. van Gijlswijk and Jordy Spreen, 'Energie- en milieu-aspecten van elektrische personenvoertuigen', *Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek*, 7 April 2015, 14; and: Karoline Steinbacher, Minke Goes and Korinna Jörling, 'Incentives for Electric Vehicles in Norway: Fact Sheet', *Ecofys* and *Adelphi*, 3 September 2018, 3.
[91] Standing Committee of the Tenth National People's Congress, 'Renewable Energy Law of the People's Republic in China', 28 February 2005.
[92] Gong et al., 'New energy vehicles in China', 210.

Science and Technology (MoST); ministries that are more concerned with the promotion and development of high-end industry and technology.[93]

The argument that the deployment of PEVs helps China's automotive sector to leapfrog foreign competitors and establish itself as global market leader has more potential. PEVs have been emphasized as one of China's ten most important 'emerging strategic industries' in the 12th and 13th FYPs and the Made in China (MIC) 2025 roadmap – China's primary manufacturing strategy.[94] In this latter document it is also said that the new energy vehicle (NEV) supply chain has to be 70% domestic by 2025.[95] These ambitious goals have been followed up by subsidies, regulations and other policy measures that have significantly expanded the Chinese PEV sector at the cost of non-Chinese PEV and battery manufacturers. This has led to the fact that only 4% of PEVs sold in China are foreign.[96] This sharply contrasts the 56% share that non-Chinese brands held in China's overall car market in 2017.[97] This is striking, given that China is now by far the largest producer of and market for both ICEVs and PEVs and thus in the most ideal position to reach economies of scale and lead the commercialization of PEVs.[98] However, despite the convincing argument that economic considerations are the primary driver behind China's decision to develop PEVs, it will become evident that these economic considerations are in fact integral and subjugated to the government's attempts to reduce oil imports and enhance China's energy security. This will become evident throughout the remainder of this chapter

2.2 "New energy vehicles"

Although PEVs became a focus area for the Chinese government back in 1995, it was not until a decade later that the first models entered the Chinese markets. Around that time, the R&D phase had ended and the first major pilot was initiated in the form of the Ten-Cities-Thousand-Vehicles Program in 2009.[99] This initiative, that sought to penetrate China's ten most prominent cities with PEVs, coincided with an address of President Hu Jintao to Congress, wherein he said that new energy

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[93] Yunshi Wang, 'China's PEV Deployment' (version 21 June 2017) http://roadmapforth.org/program/presentations17/China-YunshiWang.pdf, 30 December 2018.
[94] Central Committee of the Communist Party of China, 'The 12th Five-Year Plan for Economic and Social Development of the People's Republic of China (2011-2015)', 2010, Part III, Chapter 10, Section 1 - Section 2; and: Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', 2015, Part V, Chapter 23, Section 1, Box 8.
[95] State Council of the People's Republic of China, 'Made in China 2025', 7 July 2015, Section 3.5.
[96] Roland Irle, 'China Plug-in Vehicle Sales for the 1st Half of 2018', (version 28 November 2018) http://www.ev-volumes.com/country/china/ 28 November 2018.
[97] China Association of Automobile Manufacturers, 'The market share of Chinese brand PCs up yearly', (version 15 January 2018), http://www.caam.org.cn/AutomotivesStatistics/20180115/1305214915.html 29 November 2018.
[98] China Association of Automobile Manufacturers, 'NEV enjoyed strong development', (version 15 January 2018), http://www.caam.org.cn/AutomotivesStatistics/20180115/1305214916.html, (29 November 2018; and: Laurie Burkitt, 'The World's Largest Electric Vehicle Maker Hits a Speed Bump', *MIT Technology Review* (version 8 May 2017) https://www.technologyreview.com/s/604335/the-worlds-largest-electric-vehicle-maker-hits-a-speed-bump/ 31 December 2018.
[99] Bohnsack, 'Local niches and firm responses in sustainability transitions', 20.

vehicles 'conformed with [the] nation's current conditions'[100] and continued to explain how the rising number of Chinese vehicles posed a threat to energy consumption and environmental pollution.[101]

Two years earlier, the government had officially adopted the phrase 'new energy vehicles' to refer to BEVs, plug-in hybrid electric vehicles and fuel cell vehicles.[102] This name is interesting in itself, because it deviates from the collective name that most other countries have adopted: 'zero emission vehicles' (ZEVs).[103] There is an argument to be made that, by doing so, the government has deliberately disconnected PEVs and FCVs from environmental concerns and, instead, tied these vehicles to a search for new energy sources and away from oil.

To illustrate this, the Netherlands invited China to join the Zero Emission Vehicle Alliance during a Dutch state visit to China in 2018. Besides the fact that China refused this offer,[104] the round table where the formal invitation was issued, had been officially named the 'Sino-Dutch Round Table on New Energy Vehicles' after an earlier name that included 'zero emission vehicles' had been rejected. Allegedly, Chinese officials had not felt comfortable with the ZEV-phrase, as it implied too much that the deployment of PEVs and FCVs was tied to a responsibility to reduce GHG emissions.[105] This has also been named as a reason for China's refusal to join the ZEV Alliance.[106]

Chinese discomfort with 'zero emission vehicles' was best revealed when the China Automotive Technology and Research Center (MIIT's primary automotive think-tank) joined the University of California's ZEV Policy Lab in 2014.[107] Striking is that the memorandum of understanding between the two parties never refers to the partnership as the 'Zero Emission Vehicle Policy Lab' and is in fact formally established as the 'China-U.S. ZEV Policy Lab.' 'Zero emission vehicles' is spelled out only once in the document and refers to a specific Californian policy that is unrelated to the Sino-American partnership. In fact, when referring to PEVs and FCVs, the memorandum uses 'New Energy Vehicle(s)' in areas of cooperation and makes clear distinctions

[100] Hui He, Lingzhi Jin, Hongyang Cui and Huan Zhou, 'Assessment of electric car promotion policies in Chinese cities,' *International Council on Clean Transportation*, October 2018.
[101] Cao Shubin, '胡锦涛:发展新能源汽车符合我们国情' (translation: 'Hu Jintao: Developing new energy vehicles is in line with our national conditions'), *China Central Television* (version 9 March 2009) http://cctvenchiridion.cctv.com/special/C22908/20090309/106558.shtml 31 December 2018.
[102] The number of FCVs is so insignificant that 'NEVs' virtually always refer to PEVs; Gong et al., 'New energy vehicles in China', 210.
[103] Zero-Emission Vehicle Alliance, 'Members', (Version 29 November 2018) http://www.zevalliance.org/members/, 29 November 2018.
[104] Rong Wenwei, 'Closing speech by Rong Wenwei, general-manager of Shanghai International Automobile City', *Sino-Dutch Round Table on New Energy Vehicle Policies*, Shanghai, 12 April 2018.
[105] Anne te Velde, 'Interview with Anne te Velde, infrastructure and environment counsellor of the Embassy of the Kingdom of the Netherlands in Beijing, conducted by Merijn Drenth', 25 April 2018.
[106] Another and perhaps more decisive factor is that the ZEV Alliance is dominated by Western states and subdivisions; Anne te Velde, 'Interview with Anne te Velde.
[107] The Phrase 'zero emission vehicles' originated from California; Yergin, *The Quest*, 698.

between 'ZEVs' and 'NEVs' in the Californian and Chinese contexts respectively when talking about the exchange of policies and knowledge.[108]

The use of 'new energy vehicles' in Chinese policies has been very consequent throughout the last decade. The 'Development Plan of Energy-Saving and New-Energy Vehicles Industry (2012-2020)' -the first major roadmap for NEVs, published by the State Council in 2012- is an example of this and illustrates how this terminology can be interpreted within an energy security context. Most importantly is that the Development Plan defines NEVs as 'vehicles that use new power systems and are driven entirely or mainly by new energy sources.'[109] This defines NEVs as a break-away strategy from oil before anything else. This becomes even more evident when looking at the State Council's formal explanation for why NEVs and energy-saving vehicles should be developed.

'The development of energy-saving and new energy vehicles is an important measure to reduce vehicle fuel consumption, alleviate the contradiction between fuel supply and demand, reduce exhaust emissions, improve the atmospheric environment, and promote technological progress and optimization of the automotive industry.'[110]

Here, NEVs are in the first place regarded as a vital tool to alter China's problematic fuel economy <u>before</u> their potential to tackle environmental or economic concerns. This is consistently done in various policy documents and illustrates how important the role of oil security is in China's decision to develop PEVs.[111]

2.3 Energy security narratives in guiding policies

A more comprehensive study of MIC2025, the 12th and 13th FYPs also reveals the importance of energy security in China's most influential policies. For example, the introduction of the 12th FYP talks specifically about the challenges of 'energy security,'[112] whereas the 13th FYP starts with concerns about 'traditional and non-traditional security threats,' the observation that 'resource constraints grow increasingly tight' and that China ought to 'prepare […] for worst-case scenarios.'[113]

[108] University of California and China Automotive Technology and Research Center, 'Memorandum of Understanding on the Establishment of the China-U.S. ZEV Policy Lab between the Regents of the University of California, on Behalf of Its Davis Campus and China Automotive Technology and Research Center', 7 September 2014.
[109] State Council of the People's Republic of China, 'Development Plan of Energy-Saving and New-Energy Vehicles Industry (2012-2020)', 28 june 2012.
[110] State Council of the People's Republic of China, 'Development Plan of Energy-Saving and New-Energy Vehicles Industry (2012-2020)'.
[111] Ministry of Industry and Information Technology, 'Notice on Carrying out the Pilot Project of Energy-Saving and New Energy Vehicles', 30 November 2012; and: Ministry of Industry and Information Technology, 'Notice of the Three Departments on Energy-Saving and New Energy Vehicles', 7 May 2015; and: Ministry of Industry and Information Technology, 'Notice of the Three Ministries and Commissions on the Issuance of the Medium and Long-Term Development Plan for the Automobile Industry', 25 April 2017.
[112] Central Committee of the Communist Party of China, 'The 12th Five-Year Plan for Economic and Social Development of the People's Republic of China (2011-2015)', Part I, Chapter 1.
[113] Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Part I, Chapter 1.

Given that FYPs determine China's overall direction for five years, the importance of the inclusion energy security in their introductory chapters should not be underestimated. After all, ministries and local governments all interpret FYPs as China's ultimate policy.[114] Energy security is indeed a dominant theme in the latter FYP and discussed comprehensively in Part VII (diversification strategies, development of unconventional oil, energy storage facilities, et cetera).[115]

Part V formulates six industrial focus areas that the government regards as China's 'emerging strategic industries,' which form the basis of MIC2025. NEVs are one of these industries and their inclusion is often cited as evidence that economic motivations are the main driver for NEVs.[116] However, for a manufacturing roadmap, MIC2025 is very concerned with matters of 'national security,' 'national defense,' and the 'integration of military and civilian manufacturing.'[117] In fact, these securitized narratives -energy security in particular- seem to play an important role in the developments of the strategic industries in both MIC2025 and the 13th FYP. For example, the paragraph on 'Marine Engineering Equipment and High-Tech Vessels' is concerned with 'develop[ing] equipment and systems for deep-water exploration, ocean drilling, seafloor resources exploration and development,'[118] while Advanced Chemical Machinery should 'accelerate research and development on key equipment for the integration of the oil refining and chemical industries as well as for the intensive processing of downstream petrochemical products.'[119] Another obvious example is Advanced Rail Transit Equipment sector. In just a few years, China has developed the most extensive high-speed railway system in the world, partially to slow down the rapid increase of kerosene-devouring domestic flights.[120] This is mirrored by MIC2025's emphasis on improving 'systematic security and energy savings' in the rail sector.[121] A last example that reveals the prominence of energy security in MIC2025's strategic industry development section is 'Energy

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[114] Donghua Chen, Oliver Zhen Li and Fu Xin, 'Five-year plans, China finance and their consequences', *China Journal of Accounting Research* 10 (2017) 189-230, 190-191, 194-197.

[115] Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Part VII, Chapter 30, Box 11.

[116] Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Chapter 23, Section 1, Chapter 23, Box 8; and: Jost Wübbeke, Mirjam Meissner, Max J. Zenglein, Jaqueline Ives and Björn Conrad, 'Made in China 2025: The making of a high-tech superpower and consequences for industrial countries', *Mercator Institute for China Studies* (December 2016) 20-21, 39; and: Daniel Ren, 'Made in China 2025: world's biggest auto market wants to be the most powerful maker of electric cars', *South China Morning Post* (version 23 October 2018) https://www.scmp.com/business/china-business/article/2169698/made-china-2025-worlds-biggest-auto-market-wants-be-most 31 December 2018.

[117] State Council of the People's Republic of China, 'Made in China 2025', 1.2, 2.1, 2.2, 3.1, 3.4, 4.1

[118] Deep-water exploration, ocean drilling, seafloor resources exploration and development are activities that are unquestionably related to China's search for oil (see first chapter); Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Part V, Chapter 22, Box 7.

[119] Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Part V, Chapter 22, Box 7.

[120] Keith Bradsher, 'Speedy Trains Transform China', *The New York Times* (version 23 September 2013) https://www.nytimes.com/2013/09/24/business/global/high-speed-train-system-is-huge-success-for-china.html 31 December 2018.

[121] State Council of the People's Republic of China, 'Made in China 2025', 3.6.5.

Storage and Distributed Energy,' which focusses heavily on the development of new and sustainable energy sources and storage capacities.[122]

What MIC2025 and the FYPs reveal is that these emerging strategic industries are not 'strategic' in an economic sense, but in a way that improves China's national security and its capacity to be self-reliant. This gives a whole different meaning to MIC2025's demands that '70% of the essential spare parts and key materials' of these industries should 'have domestic sources' by 2025.[123] Rather than viewing this as China's attempt to dominate these industries, it should be seen as China's attempt to gain control over sectors that it considers as vital for its self-determination and national security (further below, this becomes evident as well).[124] This makes MIC2025 a perfect example of China's reformed vision of strategic self-reliance within the global economy (as was discussed in chapter one). The denomination of NEVs as a 'strategic industry,' therefore implies that they are primarily viewed as being vital to China's (energy) security and self-reliance.

2.4 Plug-in electric vehicle policies and developments

However, framing something as an energy security issue is unconvincing when talk is not followed up by actions. As the world's largest vehicle market, it is also possible that China has obtained its status as largest PEV market through the forces of the market. However, this is not the case, as it is widely known that PEVs worldwide are currently dependent on financial stimuli and other incentives.[125] In China, this is no different, as PEVs can easily cost two or three times more than ICEVs.[126]

However, this did not stop China from obtaining a 2,2% PEV market share in 2017, which makes it the only middle-income country with a market share higher than 0,1%.[127] In fact, China's share of PEVs is significantly larger than that of all major markets in the first world (US, 1,2%; Japan, 1%; Germany, 1,6%; France, 1,7%, the United Kingdom, 1,7%; and South Korea, 0,5%) and is surpassed only by that of Finland (2,6%), the Netherlands (2,7%), Sweden (6,3%) and Norway (39,2%).[128]

This high market share is the result of very ambitious goals that are backed by aggressive policies. In 2012, the earlier mentioned Development Plan dictated that 500.000 NEVs should be

[122] Central Committee of the Communist Party of China, 'The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)', Part V, Chapter 23, Box 8.
[123] State Council of the People's Republic of China, 'Made in China 2025', 7 July 2015, 3.3.
[124] Wübbeke et al., 'Made in China 2025', 20-21, 39; and: Daniel Ren, 'Made in China 2025: world's biggest auto market wants to be the most powerful maker of electric cars', *South China Morning Post* (version 23 October 2018) https://www.scmp.com/business/china-business/article/2169698/made-china-2025-worlds-biggest-auto-market-wants-be-most 31 December 2018.
[125] *International Energy Agency*, 'Global EV Outlook 2018', 22.
[126] Qinghua Diao, Wei Sun, Xinmei Yuan, Lili Li and Zhi Zheng, 'Life-cycle private-cost based competitiveness of electric vehicles in China considering the intangible cost of traffic policies', *Applied Energy* 178 (2016) 567-578, 569.
[127] *International Energy Agency*, 'Global EV Outlook 2018', 114.
[128] Ibidem.

produced and sold annually by 2015 and 2 million by 2020.[129] Back then, this seemed almost surreal as passenger PEVs numbered only 7.000 and, sure enough, this goal was not achieved.[130] However, an impressive 300.000 PEVs had nonetheless been produced and sold in 2015 and a year later China did surpass the 500.000 mark.[131] The reason for this rapid PEV surge from 7.000 PEVs in 2012 to more than 1,2 million in 2017, has almost solely been the result of comprehensive government stimuli.[132] Whereas in most countries PEVs receive modest (financial) benefits, the central and local governments in China grant a wide range of exceptionally generous incentives to PEVs (including subsidies, special license plates, tax exemptions, bus lane access, charging and parking fee reductions).[133] Depending on the height of the local subsidies (which come in addition to the central subsidies), tax exemptions and technical requirements, financial benefits for PEVs in China can climb up to thousands of dollars. For example, in Shanghai a single passenger BEV was eligible for as much as 28.615 USD in subsidies in 2014 and 2015.[134]

These PEV stimuli completely outmatch those of all other counties and show how serious China is about replacing ICEVs with PEVs.[135] In fact, the government goes even further than incentives. In 2017, MIIT, NDRC and MoST announced the NEV Policy Mandate, which requires all car manufacturers to obtain a sales volume of at least 10% in NEV credits in 2019 and 12% in 2020.[136] Additionally, they increased China's 2020 goal of one million NEVs to two million units and added an annual sales and production target for 2025: seven million.[137]

The closed nature of the Chinese government makes it is impossible to pinpoint exactly how much China spends on PEV development. One prominent scholar stated that in 2015 the central

[129] State Council of the People's Republic of China, 'Development Plan of Energy-Saving and New-Energy Vehicles Industry (2012-2020)'.
[130] *International Energy Agency*, 'Global EV Outlook 2018' 114.
[131] China Association of Automobile Manufacturers, 'The growth of new energy vehicles exceeded 50%' (Version 24 February 2017) http://www.caam.org.cn/AutomotivesStatistics/20170224/1405205543.html 30 November 2018.
[132] *International Energy Agency*, 'Global EV Outlook 2018', 111; and: Tyfield and Zuev, 'Stasis, dynamism and emergence of the e-mobility system in China', 263.
[133] Nederland Elektrisch, 'Subsidies en financiering', (versie 30 November 2018) https://nederlandelektrisch.nl/home, 30 November 2018; and: Nic Lutsey and Peter Slowik, 'The Continued Transition to Electric Vehicles in U.S. Cities', *International Council on Clean Transportation* (July 2018) 3-4; and: Dale Hall, Hongyang Cui and Nic Lutsey, 'Electric Vehicle Capitals of the World: What Markets are Leading the Transition to Electric?', *International Council on Clean Transportation* (November 2017) 3-6.
[134] Wang et al., 'China's electric car surge', 487.
[135] Harvey Jones, 'What's put the spark in Norway's electric car revolution?', *The Guardian* (version 2 July 2018) https://www.theguardian.com/money/2018/jul/02/norway-electric-cars-subsidies-fossil-fuel 31 December 2018; and: Uwe Tletge, Peer Mock, Nic Lutsey and Alex Campestrini, 'Comparison of Leading Electric Vehicle Policy and Deployment in Europe', *International Council on Clean Transportation* (May 2016) 54, 57-59.
[136] Credits are provided to every NEV that is sold by a manufacturer. Given that the best-performing BEVs can get up to 5 credits while PHEVs get an average of two credits, a 10% credit share does not equate a 10% NEV market share, but rather 3-4% share; International Council on Clean Transportation, 'China's New Energy Vehicle Mandate Policy (Final Rule)' (2018) 2-5.
[137] Ministry of Industry and Information Technology, Ministry of Science and Technology and the National Development and Reform Commission, 'Medium and Long-Term Development Plan for the Automobile Industry', 10 May 2017.

government spent 8,4 billion USD on PEV subsidies alone in 2015.[138] In comparison, the US -the largest PEV market until 2015- spent 'only' 865 million USD.[139] The same scholar later estimated that purchase subsidies for PEVs alone could be as high as 15 billion USD in 2020.[140] Whatever China's exact budget may be, it shows how determined the leadership is to accelerate the growth of China's PEV stock.

2.5 Protectionism or self-reliance?

As was mentioned before, Chinese policies favor domestic PEVs at the expense of foreign models. This is another reason why many scholars and news articles conclude that the government's foremost concern regarding PEVs is to transform China's automotive industry into the global market leader.[141] The fact that foreign PEVs make up only 4% of China's PEV sales and are in many instances not eligible for subsidies, provides a strong case for this assumption.[142]

Nevertheless, various factors downplay this argument. Firstly, vehicles are made up of a wide variety of components and, despite MIC2025's target that 70% of these should be domestically produced, there is no evidence that most of these components are targeted by protectionism. In fact, many foreign suppliers provide key components to Chinese PEV manufacturers and representatives of NXP Semiconductors and Prodrive Technologies, two Dutch PEV suppliers with manufacturing facilities in China, disclosed in an interview that their companies did not encounter any unfair practices.[143] Another example is Swiss-Swedish company ABB, which is one of China's largest suppliers of fast-charging infrastructure.[144]

The only key components that are clearly targeted by protectionism are PEV batteries. When LG Chem and Samsung SDI opened battery factories in China in 2015 to 'forge [a] foothold in the

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138 Yunshi Wang, 'China's PEV Deployment'.
139 Ibidem.
140 Wang et al., 'China's electric car surge', 488.
141 Bohnsack, 'Local niches and firm responses in sustainability transitions', 20, 23-26; and: Marika Heller, 'Chinese Government Support for New Energy Vehicles as Trade Battleground', *The National Bureau of Asian Research* (version 27 September 2017) https://www.nbr.org/publication/chinese-government-support-for-new-energy-vehicles-as-a-trade-battleground/ 31 December 2018.
142 Jose Pontes, '2017 China electric car sales blow world out of the water - BAIC EC-Series is a superstar', *Clean Technica* (version 29 January 2018) https://cleantechnica.com/2018/01/29/2017-china-electric-car-sales-blow-world-water-baic-ec-series-superstar/ 31 December 2018.
143 NXP Semiconductors produces power electronics for PEV batteries and Prodrive Technologies recently opened up a manufacturing base in Suzhou and is expecting to launch products for Chinese PEVs in 2020. Both Maurice Geraets of NXP and Thomas van Schijndel of Prodrive stated in interviews that the performance of their companies was not compromised by protectionism; Thomas van Schijndel, 'Interview with Thomas van Schijndel, general manager at Prodrive Technologies, by Merijn Drenth', 13 June 2018; and: Maurice Geraets, 'Interview with Maurice Geraets, managing director at NXP Semiconductors', by Merijn Drenth, 25 May 2018.
144 Nick Flaherty, 'ABB in top five suppliers of charging stations in China', *eeNews* Automotive (version 16 June 2016) http://www.eenewsautomotive.com/news/abb-top-five-suppliers-charging-stations-china 31 December 2018.

world's biggest new energy vehicle market.'[145] The central government thwarted their ambitions and published a list of companies that were allowed to supply batteries in China. Not a single foreign manufacturer was included.[146] The government's protectionist attitude towards batteries is also the reason why many foreign PEVs cannot apply for central subsidies. If a PEV wants to be included in MIIT's subsidy catalogue, it has to have a Chinese battery.[147] Since most non-Chinese PEVs run on Japanese or Korean LIBs, very few of them are eligible for subsidies. The ones that are all run on Chinese batteries.[148]

It is in fact regional -not national- protectionism that is mainly responsible for the low share of foreign PEVs in China. Regional governments have a right to distribute additional subsidies and financial incentives. This has led to requirements that mostly benefit locally produced PEVs at the expense of non-local and foreign vehicles.[149] Given that the central government actively fights these unfair practices undermines the argument that it gives Chinese PEV manufacturers a false head-start by fostering protectionism (the 'economic' argument). The fact that LIBs are the exception to this only strengthens the assumption that PEV development in China is predominantly driven by energy security.

2.6 China's battery ambitions

After all, PEVs might be powered by the electricity grid, but it is the battery pack in the vehicle that stores and distributes power to the electric motor. This makes batteries the most essential PEV component. Not surprisingly, battery packs are therefore a cornerstone of China's PEV industry and their importance is emphasized in many NEV policies, including MIC2025.[150] This explains why MIC2025's 70% target seems to affect batteries only.[151] MIC2025 (as was concluded earlier) is the embodiment of the government's modern interpretation of self-reliance and concerned with (energy) security. It therefore makes sense that batteries -not drivetrains or charging hardware- are defined by the central government as 'key materials,' as they play an indispensable role as the energy carriers of China's envisioned future transport systems.[152] Batteries are therefore a responsibility that the Chinese government does not want to delegate to foreign companies.

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[145] Henry Sanderson, Tom Hancock and Leo Lewis, 'Electric cars: China's battle for the battery market', *Financial Times* (version 5 March 2017) https://www.ft.com/content/8c94a2f6-fdcd-11e6-8d8e-a5e3738f9ae4 31 December 2018.
[146] Sanderson et al., 'Electric cars', 5 March 2017.
[147] Ibidem.
[148] Robert Castellano, 'China's New Electric Vehicle Regulation will Weigh on Tesla', *Seeking Alpha* (version 15 February 2018) https://seekingalpha.com/article/4147329-chinas-new-electric-vehicle-regulation-will-weigh-tesla 31 December 2018.
[149] Bohnsack, 'Local niches and firm responses in sustainability transitions', 27-28.
[150] State Council of the People's Republic in China, 'Made in China 2025', 3.6.6.
[151] Ibidem, 3.3.
[152] Ibidem.

The Chinese battery industry has indeed grown significantly over the past decade and now aims to challenge the Japanese and Korean industries that currently dominate the global market.[153] Nowadays, seven of the ten largest LIB producers in the world are Chinese. Like its PEV industry, China's battery industry has been able to grow so quickly due to generous financial support from the central government that has been favoring battery makers, BYD and CATL in particular.[154] China's largest LIB manufacturer, BYD, also happens to be the world's largest producer of PEVs.[155] The company was founded back in 1995 and started producing its first batteries two years later (it was not until 2003 that BYDs first vehicles were produced).[156]

Whether BYDs founding moment is related to China's return to oil imports and the government's contemporary focus on PEV R&D and energy security is hard to say. However, nowadays it is widely accepted that the current rise of China's battery industry is intertwined with its PEV industry.[157] Whereas rechargeable batteries used to power small consumer devices over the past decades, they now face the daunting task of powering buses, cars and perhaps even more heavier modes of transport in the distant future. The speed, range, longevity and price of PEVs all depends on the performance of their batteries. Since the Chinese government cannot subsidize its growing PEV market forever, it will have to further develop LIBs and scale up production capacities to make PEVs economically viable. Nonetheless, the development of a domestic battery industry is mostly essential for the central government since, without it, Chinese PEVs would be dependent on imported batteries. As it turns out, these happen to be produced predominantly in countries that are firmly entrenched within the American sphere of influence.

Therefore, this chapter concludes that energy security -not environmental or economic- concerns are central to the government's PEV ambitions. Given the long-standing and increasing importance of these vehicles in China's guiding policies, as well as the fact that they have consistently been framed in an energy security context, it has become evident that the Chinese government has regarded PEVs as the primary solution to China's oil dependency problem since the mid-1990s. Even though the government always refers to 'NEVs,' the emphasis has been overwhelmingly on PEVs. This becomes evident when looking at policies, China's investments in battery industries, the roll-out of charging infrastructure and the simple fact that PEVs vastly outnumber FCVs.[158] However, the next chapter will demonstrate that PEVs might not offer the promise of energy security that the Chinese government is searching for after all.

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153 Sanderson et al., 'Electric cars', 5 March 2017.
154 Ibidem.
155 Akito Tanaka, Takashi Kawakami and Yukhiro Omoto, 'Battery wars : Japan and South Korea battle China for future of EVs', *Nikkei Asian Review* (version 14 November 2018) https://asia.nikkei.com/Spotlight/Cover-Story/Battery-wars-Japan-and-South-Korea-battle-China-for-future-of-EVs 31 December 2018.
156 BYD, 'History' (version 24 December 2018) http://bydeurope.com/company/history.php 24 December 2018.
157 Tanaka et al., 'Battery wars', 2018.
158 1,2 million passenger PEVs versus 1.000 FCVs; He et al., 'Assessment of electric car promotion policies in Chinese cities', 8, 14-19, 25, 28-33.

3. The downsides of plug-in electric vehicles

In the previous chapter it was concluded that the Chinese central government has regarded plug-in electric vehicles (PEVs) as the most promising solution to China's dependency on imported oil since 1995. However, it was also suggested that this might no longer be the case. The starting point of this assumption is the increasing interest of the Chinese government in fuel cell vehicles (FCVs) around the same time (2016) that government support for PEVs started to be reduced. However, this will be discussed in the next chapter. This chapter will examine what elements and aspects of PEVs and the lithium-ion battery (LIB) supply chain might have undermined the energy security potential of PEVs in the eyes the Chinese government.

3.1 From lead-acid to lithium-ion batteries

The core component defining a PEV is its battery pack. Although batteries have been around since the nineteenth century, it was not until the 1980s and 1990s that the global battery industry started to grow as a result of the consumer electronics revolution. At the time, many battery types existed, however, due to their infant stage, it was uncertain which type would dominate electronic devices in the future, let alone entire vehicles. From the late 1990s and throughout the 2000s, the answer to this shifted into the direction of lead-acid batteries. Around that time, the amount of electric bikes and scooters with such batteries in China exploded from 40.000 in 1998 to ten million in 2005.[159] Subsequently, the use of lead-acid batteries was extended to tricycles, low-speed vehicles and PEVs, causing the production of these batteries to grow dramatically in the early 2010s.[160] Lead-acid batteries are fairly cheap and, most importantly to the government, their core materials -lead and sulfur- are abundantly available. In fact, China is currently the world's largest producer of both materials, making it safe to assume that PEVs with lead-acid batteries were regarded by the government as a much more secure solution than oil as a vehicle's main power source.[161]

159 Jonathan Weinert, Chaktan Ma and Christopher Cherry, 'The transition to electric bikes in China: history and key reasons for rapid growth' *Transportation* 34 (2007) 3, 301-318, 303.
160 Rongbo Zhang, Zuo Cheng, Ruirui Zhao, Hongyu Chen and Yeuhong Shu, 'Influence of Environmental Policies in China's Lead-Acid Battery Industry', *The Open Fuels & Energy Science Journal* 8 (2015) 291-297, 292.
161 Hassan Z. Harraz, 'Sulfur Ore Deposits', (version October 2015) https://www.researchgate.net/publication/301860125_Sulfur_Ore_Deposits, 24 December 2018; and: International Lead Association, 'Lead Production & Statistics' (Version 4 December 2018) https://www.ila-lead.org/lead-facts/lead-production--statistics 4 December 2018.

Despite their dominance at the start of this decade, lead-acid batteries as battery packs for PEVs have now been replaced almost entirely by LIBs. Increasing lead prices and the health and environmental hazards of lead-acid battery production caused this shift initially.[162] However, superior energy and power density, efficiency and longevity led LIBs to overtake lead-acid batteries later on.[163] Nowadays, LIBs are absolutely crucial for large scale commercialization of PEVs, as range, longevity, charging time, speed and the size of vehicles are all decisive consumer considerations that can currently only be tackled by LIBs.[164]

3.2 The lithium problem

However, the shift towards LIBs is problematic for the Chinese government from an energy security point of view. LIBs consist of various rare metals that have to be imported from outside of China and run the risk of becoming unavailable or depleted in the future. The demand for lithium, is said to triple between 2018 and 2025 due to the growth of the global PEV stock and scholars are divided whether the known lithium reserves are large enough to support the global PEV stock in the long term.[165] Scholars Diouf and Pode calculate that replacing the world's one billion cars 'would use op to 30% of the world's known reserves of lithium.'[166] Delucchi et al., are more positive and argue that lithium 'can support the economic development of a very large global EV fleet […] lasting for a century or so,' when taking into account lithium recycling and ocean extraction.[167]

However, lithium recycling is currently very expensive and exploring ocean beds for additional lithium deposits does not alleviate the Chinese government's sense of energy insecurity.[168] Even if lithium deposits are abundant enough, the demand for it might still outpace lithium production due to the rapid development of PEVs. Olivetti et al. point out that, between 2010 and 2014, lithium consumption grew with 73% compared to a production growth of 28%.[169] Thus, supply chain bottlenecks pose a short-term risk that could drive up global lithium prices significantly. However, most problematic is the geographical disparity of lithium deposits. The bulk of economically viable

[162] H.Y. Chen, A.J. Li and D.E. Finlow, 'The lead and lead-acid battery industries during 2002 and 2007 in China', *Journal of Power Sources* 191 (2009) 22-27, 24, 26.
[163] Boucar Diouf and Ramchandra Pode, 'Potential of lithium-ion batteries in renewable energy', *Renewable Energy* 76 (2015) 375-380, 376.
[164] Ona Egbue and Suzanna Long, 'Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions', *Energy Policy* 48 (2012) 717-729, 724.
[165] Gideon Long, 'Peru hopes to join crowded lithium market', *Financial Times* (version 9 November 2018) https://www.ft.com/content/23235344-e3fe-11e8-a6e5-792428919cee 31 December 2018.
[166] Diouf and Pode, 'Potential of lithium-ion batteries in renewable energy', 380.
[167] M.A. Delucchi, C. Yang, A.F. Burke, J.M. Ogden, K. Kurani, J. Kessler and D. Sperling, 'An assessment of electric vehicles: technology, infrastructure requirements, greenhouse-gas emissions, petroleum use, material use, lifetime cost, consumer acceptance and policy initiatives', *Philosophical Transactions Mathematical, Physical and Engineering Sciences* 372 (2014) 2006, 1-27, 15.
[168] Hakim Idjis and Pascal da Costa, 'Is Electric Vehicles Battery Recovery a Source of Cost or Profit?', in: Danielle Attias, *The Automobile Revolution: Towards a New-Electro Mobility Paradigm* (Cham 2017) 117-134, 122, 129-131.
[169] Olivetti et al., 'Lithium-Ion Battery Supply Chain Considerations', 234.

lithium deposits is concentrated in Argentina, Bolivia, Chile and Australia.[170] China is good for half of the world's lithium consumption but produces only 7%.[171] Therefore, as much as 86% of its lithium is imported and has to be shipped over far distances.[172] An additional problem is that the disproportionally large occurrence of lithium in South America makes global lithium production and prices highly vulnerable to disruptive developments within the lithium triangle.[173] All three countries have a history of political turmoil and economic instability. When this was written, Argentina suffered from a severe currency crisis while stifling regulations had resulted in unfavorable investment conditions in Chile.[174] This explains why 70% of China's lithium imports hail from Australia.[175]

3.3 The cobalt problem

A critical LIB component that is even more problematic than lithium is cobalt. Whereas scholars are divided about the availability of lithium, there exists a strong consensus that cobalt will likely be depleted in the foreseeable future due to the growth of PEVs.[176] More problematic in the short-term is that only one country hosts 50% of the world's cobalt deposits and has a 60% production share: the Democratic Republic of the Congo.[177] Congo is easily one of the most instable countries in the world and seldom far away from civil unrest or war (let alone the fact that working conditions in Congo's cobalt mines are notoriously bad).[178] Not surprisingly, Congo's instability has been cited as one of the most critical threats towards the global PEV industry.[179] Given that it is the world's largest consumer of cobalt, but contains no more than 1% of the global reserves, China has to import 96% of its cobalt from Congo. This makes its PEV and LIB industries highly vulnerable to unrest in that country.[180]

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[170] Oliveira et al., 'Key issues of lithium-ion batteries', 356.
[171] Olivetti et al., 'Lithium-Ion Battery Supply Chain Considerations', 234.
[172] Hao et al., 'China's traction battery technology roadmap', 357.
[173] Oliveira et al., 'Key issues of lithium-ion batteries', 361.
[174] Benedict Mander, 'Argentines feel the squeeze as living standards fall', *Financial Times* (version 28 November 2018) https://www.ft.com/content/4edf7302-f27f-11e8-ae55-df4bf40f9d0d 31 December 2018; and: Charles Newbery, 'Energy: differing fortunes for Argentina's lithium and biodiesel', *Financial Times* (version 24 September 2018) https://www.ft.com/content/7922c28e-956b-11e8-95f8-8640db9060a7 31 December 2018.
[175] Hao et al., 'Material flow analysis of lithium in China', 100.
[176] Hakim Idjis and Danielle Attias, 'Availability of Mineral Resources and Impact for Electric Vehicle Recycling in Europe' in: Pascal da Costa and Danielle Attias, *Towards a Sustainable Economy: Paradoxes and Trends in Energy and Transportation* (Cham 2018) 71-82, 79-80, 82; and: Sverdrup, 'Modelling global extraction, supply, price and depletion of the extractable geological resources within the LITHIUM model', 126; and: Delucchi et al., 'An assessment of electric vehicles', 13.
[177] Henry Sanderson, 'BMW launches pilot to improve cobalt mining conditions in DRC as EV sales grow', *Financial Times* (version 29 November 2018) https://www.ft.com/content/0e1a2f24-f405-11e8-9623-d7f9881e729f 31 December 2018; and: U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018', January 2018, 50-51.
[178] Todd C. Frankel, 'The cobalt pipeline: Tracing the path from deadly hand-dug mines in Congo to consumers' phones and laptops', *The Washington Post* (version 30 September 2016) https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/??noredirect=on 31 December 2018.
[179] Olivetti et al., 'Lithium-Ion Battery Supply Chain Considerations', 232.
[180] Henry Sanderson, 'China plays long game on cobalt and electric batteries', *Financial Times* (version 26 May 2016) https://www.ft.com/content/054bbb3a-1e8b-11e6-a7bc-ee846770ec15 5 December 2019.

Finally, cobalt is mined primarily as a byproduct of copper and iron and makes up only a tiny percentage in proportion to either copper or iron. Thus, as LIB supply-chain analyst Sam Jaffe puts it, 'cobalt harvesting rates from these mines is not a factor of cobalt demand or cobalt pricing, but of demand and pricing of the co-extracted minerals. Pure-play cobalt mines simply don't exist in the world today, and only a handful of small cobalt-only resource sites are known to exist.'[181] In other words, disruptions and price fluctuations in the copper and iron industries can affect the flow and costs of cobalt as well.

3.4 Back to square one

The rising dominance of LIBs in the PEV industry and the uncertainties surrounding lithium and cobalt clearly show that PEVs -and LIBs specifically- display by and large the same features that made ICEVs problematic to the Chinese government in the first place.[182] The vast majority of scholars study the supply chain of rare metals from either a geological, environmental or economic point of view, without connecting the problems of these metals to energy security. So far, only Hao et al. seem to have compared China's lithium import dependence to that of Chinese oil. Nevertheless, this comparison does not go beyond the observation that domestic production of both resources is little and that the pace of demand and import dependency outpaces global supply. Hao et al. therefore refer to lithium as a 'resource security risk' rather than a threat to energy security.[183]

The Chinese government's foremost energy security concern revolves around China's increasing dependence on imported oil and PEVs have been regarded as the most promising solution to alleviate this. Therefore, both lithium and cobalt should be studied by scholars in an energy security framework. The reason why scholars have so fair restrained from doing this is probably due to the fact that energy security studies tend to focus on traditional energy sources, renewables or electricity grids. They pay little attention to the relatively little impact that the three million PEVs in the world currently have. Let alone the rare metals that are in them. Another explanation might be the recent domination of LIBs in the PEV supply chain and, given that battery technologies are rapidly evolving, lithium and cobalt might over time be replaced by synthetic or other less problematic metals.

3.5 Beyond lithium-ion batteries?

The development of post-lithium-ion technologies is indeed one of the development goals of China's 2016 Power Battery Technology Roadmap and implies that the government refrains from viewing LIBs as an ideal energy carrier. One group of Chinese scholars studying this roadmap voiced their skepticism about the prospects of post-lithium-ion technologies. They doubt whether the roadmap's

[181] Jaffe, 'Vulnerable Links in the Lithium-Ion Battery Supply Chain', 226.
[182] Other critical minerals in LIBs are graphite, manganese and nickel, but these materials currently pose less of a threat to China.
[183] Hao et al., 'Material flow analysis of lithium in China', 105.

ambitions concerning lithium-sulfur (which contains no cobalt) and zinc-air batteries as future replacements for LIBs are feasible.[184] Indeed, future battery technologies are being developed, but the scientific community seems uncertain when or whether they will be able to replace LIBs. Powering entire vehicles requires large and heavy battery packs and the energy and power density that lithium and cobalt offer has not yet been matched by other materials.[185] To illustrate this, the efficiency of LIBs was the reason why mobile phones became much smaller and lighter during the 2000s. In the same way they are now responsible for the widespread introduction of large, fully electric vehicles - like SUVs and city buses- that are capable of driving respectable distances while having enough space for passengers and cargo.[186]

3.6 Geopolitical implications

For the Chinese government, the uncertainty surrounding battery technologies is very unfortunate indeed. Having invested billions of euros in the development and dominance of its PEV industry, Chinese companies have now been forced to acquire stakes in lithium deposits in far-flung countries. In a way this resembles the Go-Out strategy that China adopted in the 1990s when it was forced to secure its flow of oil.[187] Countries and companies have even resorted to deep-sea exploration in order to guarantee a steady supply of rare battery metals.[188]

However, the most pressing issue is that China's import share of lithium and cobalt is now higher than that of oil, which makes PEVs even more vulnerable to disruptions, conflicts, embargoes and naval blockades than ICEVs. Complicating this is that the surge of PEVs is making LIBs increasingly important in the global economy. Competition over these supply chains is increasingly becoming a geopolitical issue. As was mentioned before, China's growing importance in the battery industry has already led to clashes with traditional battery hubs, Japan and South Korea. However, there are signs that the US is becoming increasingly aware of critical changes in the global battery

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[184] China's has the second-largest zinc reserves and is the world's largest producer; U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018', 191; and: Hao et al., 'China's traction battery technology roadmap', 357.

[185] For example, lithium is the lightest solid material in the known universe.

[186] Jaffe, 'Vulnerable Links in the Lithium-Ion Battery Supply Chain', 226-227; and: Oliveira et al., 'Key issues of lithium-ion batteries', 356; and: Sverdrup, 'Modelling global extraction, supply, price and depletion of the extractable geological resources within the LITHIUM model', 126.

[187] Todd C. Frankel, 'The cobalt pipeline: Tracing the path from deadly hand-dug mines in Congo to consumers' phones and laptops', *The Washington Post* (version 30 September 2016) https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/??noredirect=on 31 December 2018; and: Sam Meredith, 'China is winning "desperate" global race to control lithium for electric vehicles', *CNBC* (version 4 December 2017) https://www.cnbc.com/2017/12/04/china-in-pole-position-amid-global-race-to-secure-lithium-supplies.html 31 December 2018; and: Akshat Rathi, 'One Chinese company now controls most of the metal needed to make the world's advanced batteries', *Quartz* (version 30 May 2018) https://qz.com/1292202/china-now-effectively-controls-half-the-worlds-lithium-production/ 31 December 2018.

[188] Henry Sanderson, 'Electric vehicles spur race to mine deep sea riches', *Financial Times* (version 14 November 2018) https://www.ft.com/content/00b2e3c8-e2b0-11e8-a6e5-792428919cee 31 December 2018; and: Henry Sanderson, 'Congo declares battery metal cobalt 'strategic' in move that triples royalties', *Financial Times* (version 3 December 2018) https://www.ft.com/content/382c3d24-f726-11e8-8b7c-6fa24bd5409c 31 December 2018.

status quo. The American Department of the Interior and the Geological Survey observed that 'lithium supply security has become a top priority for technology companies in the United States and Asia'[189] and a study by the RAND Corporation urged Washington to become more invested in steering the LIB supply chain in its favor.[190] This is partially due to the scarcity of lithium and cobalt. However, the report's largest concern is China's growing dominance in the supply chain. This has already led to the fact that American military technologies no longer depend on batteries from the US or 'strong U.S. allies (Japan and Korea)' only, but 'will become increasingly reliant on a foreign supply chain that includes Chinese manufacturers.'[191] The report continues that 'this presents a potential vulnerability in the supply chain for RSPBs [rechargeable soldier-portable batteries] in the event of any type of economic, political, or military conflict with China.'[192] Undoubtedly, such reasoning from one of the most influential government-funded think tanks in the US must be alarming to the Chinese government and strongly undermines the energy security potential of PEVs.

3.7 Limitations for military use

Even if batteries were to evolve beyond lithium-ion technologies, they pose other limitations that could be perceived as problematic by the Chinese government. Recent technologies might have enabled the deployment of electric city buses and large passenger cars with a respectable range, but the prospects of electric military vehicles is currently very limited. Their sheer size and weight would require exceptionally high energy and power capacities of battery packs.[193] This has already made the prospects for long-haul electric coaches and trucks problematic, but various factors make electric military vehicles even more challenging. Their batteries will have to be capable of defying rough terrain and executing military and silent watch duties.[194] Aside from size and weight, batteries would also be highly disadvantageous in this regard due to their notoriously bad performance in cold weather conditions, slow charging time, and discharge rates, which makes them unsuitable for prolonged stationary positions.[195] Lastly, LIBs are a vulnerable technology and their performance could be seriously hampered after severe impacts on the vehicle.[196]

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[189] U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018' 99.
[190] Richard Silberglitt, James T. Bartis and Kyle Brady, 'Soldier-Portable Battery Supply: Foreign Dependence and Policy Options', *RAND Corporation* (2014) 12-13, 14-18.
[191] Silberglitt et al., 'Soldier-Portable Battery Supply', 12-13.
[192] Ibidem, 12.
[193] Brendan Sims and Simon Crase, 'Review of Battery Technologies for Military Land Vehicles', *Australian Government: Department of Defence, Science and Technology* (2017) 32.
[194] Sims and Crase, 'Review of Battery Technologies for Military Land Vehicles', 32.
[195] With regard to cold weather conditions: the performance capacity of LIBs in passenger PEVs in −10°C conditions is only two thirds of that of a LIB operating in +25°C conditions; with regard to slow charging time: Charging an electric truck with a range of 200km takes three to five hours; with regard to prolonged stationary positions: Batteries are permanently 'leaking' energy, even when turned off; J. Jaguemont, L. Boulon and Y. Dubé, 'A comprehensive review of lithium-ion batteries used in hybrid and electric vehicles at cold temperatures', *Applied Energy* 164 (2016) 99-114, 101; and: Emoss, 'Electric trucks: the future for inner city distribution is here' (Version 8 December 2018) http://www.emoss.nl/en/electric-vehicles/full-electric-truck/ 8 December 2018.
[196] Sims and Crase, 'Review of Battery Technologies for Military Land Vehicles', 7-8.

In chapter one, it was mentioned that, in the 1950s, the Chinese government's foremost concern regarding oil import dependency had been the fact that foreign powers were able to cripple China's military capabilities by cutting off China's oil supplies. Provided that the government still regards this as a liability, PEVs are no solution to this problem other than that an uptake of civilian PEVs would leave more oil for military use. Electric military vehicles are simply no feasible alternative to ICEVs for decades to come. However, the fact that LIBs perform badly in cold weather is not only an obstacle for the military, but for regular PEVs as well. Northern and western China are subject to very cold winters and during the Sino-Dutch Roundtable on NEVs in 2018, this was cited by the Chinese participants as a big obstacle for the deployment of PEVs in China.[197]

3.8 Smart grids

Finally, there are security concerns with the electricity grid itself. In China, the grid might be powered largely by domestically produced and therefore secure resources, but it has historically been plagued by frequent blackouts and shortages.[198] On top of that, there are ongoing discussions whether electricity grids are actually capable of supporting millions of PEVs.[199] The International Council on Clean Transportation calculated that China's grid is much more vulnerable to large scale PEV deployment than grids of other countries. This is partially due to the fact that it is run by just two giant state-owned grid companies, the State Grid Corporation of China and the Southern China Power Grid.[200] As a consequence, China's electricity grid is extremely interconnected, meaning that an abnormal occurrence or failure within the grid has a much higher chance of causing chain reactions that can lead to large-scale blackouts. Such events can not only be caused by large amounts of plugged-in PEVs, but PEVs run the risk to be at the receiving end as well. Either way, severe blackouts could theoretically paralyze the entire transport system.

The introduction of the smart grid has the potential to facilitate a large PEV stock.[201] For example, many PEVs are being charged during the night and smart grids and chargers can prevent the overheating of the grid by regulating electricity flows. Plugged-in PEVs can even act as additional energy storage systems that can provide power to the grid when power plants are not able to provide

[197] Rong Wenwei, 'Closing speech by Rong Weinwei; and Bin Liu, 'Remarks by Bin Liu, director of financial and tax department for China Automotive Technology and Research Center', *Sino-Dutch Round Table on International Cooperation on New Energy Vehicle Policies*, Shanghai, 12 April 2018; and: Yonghe Huang, 'Remarks by Yonghe Huang, Chief Engineer for China Automotive Technology and Research Center', *Sino-Dutch Round Table on International Cooperation on New Energy Vehicle Policies* (Shanghai, 12 April 2018).
[198] Elspeth Thomson, 'Power Shortages in China: Why?', *China: An International Journal* 3 (2005) 1, 155-171, 155-157.
[199] Kevin Bullis, 'Could Electric Cars Threaten the Grid?', 16 August 2013; and: Nick Stockton, 'Electric car could destroy the electric grid – or fix it forever', *Wired* (version 2 March 2018) https://www.wired.com/story/electric-cars-impact-electric-grid/ 31 December 2018.
[200] *International Council on Clean Transportation*, 'Electric Vehicle Grid Integration in the U.S., Europe and China: Challenges and Choices for Electricity and Transportation Policy' (July 2013) 25, 42.
[201] The smart grid is a digital 'communication network overlaid on top of the traditional power grid,' able to monitor and manage the grid and prevent or limit power outages; Sanjay Goel and Yuan Hong, 'Security Challenges in Smart Grid Implementation', in: Sanjay Goel, Yuan Hong, Vagelis Papakonstantinou and Dariusz Kloza, *Smart Grid Security* (London 2015) 1-39, 1.

enough power to the electricity grid alone. That being said, the digitalization of the electricity grid means that China's grid, as well as its PEV stock, will be vulnerable to cyberattacks.[202] Thus, aside from targeting China's homes, industries and government buildings, cyberattacks could also paralyze China's transport system. This makes PEVs a vulnerable target for third party aggressors, such as nation states or terrorist organizations, in a way that ICEVs are not. Finally, making China's entire vehicle stock dependent on the electricity is in itself fundamentally at odds with a fundamental dimension of energy security. The energy diversification principle dictates that relying too much on one source of energy makes a country more vulnerable to energy security threats.[203] Adding millions of cars to a grid that is already responsible for electrifying the homes and offices of the world's most populous country in the world is in itself a threat to energy security.

When taking into account all of the above, it can be concluded that PEVs do not offer the energy security solution that the Chinese government had initially expected. Most important is that current battery technologies are heavily dependent on problematic materials that have to be imported and are vulnerable to disruptions. These features made oil China's foremost energy security issue in the first place. In addition, significant technological obstacles have to be overcome to make PEVs suitable for widespread heavy-duty and military applications and there is a lot of uncertainty whether future batteries have the capacity to overcome these obstacles. Moreover, making China's entire vehicle stock dependent on the electricity grid makes PEVs susceptible to brand new energy security risks. All in all, this chapter has provided enough reason to examine whether the government's strategy to secure energy security has shifted from PEVs to FCVs.

[202] Goel and Hong, 'Security Challenges in Smart Grid Implementation', 7-8.
[203] Andy Stirling, 'The Diversification Dimension of Energy Security', in: Benjamin K. Sovacool (ed.), *The Routledge Handbook of Energy Security* (Abingdon 2011) 146-175, 146-147, 150-151.

4. The emergence of fuel cell vehicles

The previous chapter established that plug-in electric vehicles (PEVs) pose a significant risk to the Chinese government's perception of what constitutes energy security. this last chapter will examine whether Chinese policy reflects this as well. It will juxtapose Chinese PEV developments and policies since 2016 with developments and policies in the field of fuel cell vehicles (FCVs) and analyze whether the increasing interest of the Chinese government in FCVs has been the result of its decreasing trust in the capabilities of PEVs to take away China's energy insecurities.

4.1 Policy shifts

If there has been a policy shift from PEVs towards FCVs, the turning point appears to be 2016. In that year, no less than three roadmaps were published by the National Development and Reform Commission, the China National Institute for Standardization and the Society of Automotive Engineers of China.[204] The Fuel Cell Vehicle Technology Roadmap (henceforth referred to as 'the Roadmap') that the latter organization published is the most influential of the three documents. It is also the only one that has been translated into English and will therefore be the only that is being studied for this thesis.

Up until 2016, no specific FCV roadmaps had been published in China and FCVs in general received fairly little interest from the government. While China already dominated global PEV sales and production, very few FCVs (110) existed in China in 2016 when compared to other countries (18.364 in the US, 1.863 in the EU and 913 in Japan).[205] The Roadmap's announcement to deploy over 5.000 FCVs and 100 hydrogen refueling stations (HRSs) in 2020 and more than a million FCVs and over 1.000 HRSs in 2030 was therefore unexpected and bold. So far, no other country but Japan had formulated FCV production targets, let alone the fact that China was -and still is- lagging behind significantly in hydrogen technology.[206]

[204] The National Development and Reform Commission, a ministry-level macro management agency, published the Innovation Action Plan and Roadmap in 2016. It establishes hydrogen and FCVs as one of the NDRC's fifteen key tasks; the 2016 Bluebook on Hydrogen Energy Industrial Infrastructure was published by the China National Institute for Standardization and the National Standardization Technical Committee on Hydrogen Energy.
[205] This includes all FCVs, from fork trucks to city buses; Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 28 October 2016; and: Sunita Satyapal and Mike Mills, 'IPHE Country Update November 2016: United States', *International Partnership for Hydrogen and Fuel Cells in the Economy*, November 2016; and: Katarzyna Drabicka, 'IPHE Country Update Nov 2016: European Commission', *International Partnership for Hydrogen and Fuel Cells in the Economy*, November 2016; and: Masaru Yamazumi and Shinya Kawamura, 'IPHE Country Update November 2016: Japan' *International Partnership of Hydrogen and Fuel Cells in the Economy*, November 2016.
[206] Yamazumi and Kawamura, 'IPHE Country Update November 2016'; and: Bart Biebuyck, 'Interview with Bart Biebuyck.

Important is that this turning point coincided with two other developments. First is that not long after the roadmaps were published, the Chinese Ministry of Finance announced that, starting in January 2017, central subsidies for PEVs would be gradually reduced and abolished by 2020 and that local subsidies could at most be 50% of the central subsidies.[207] Contrasting the sharp decline of PEV subsidies is the funding that FCVs receive. As of May 2018, the height of FCV subsidies stood at 32.000 USD per passenger vehicle while fuel cell trucks and buses receive somewhere between 48.000 USD and 79.000 USD (California has the most generous purchase subsidies behind China with 5.000 USD for passenger FCVs).[208] The construction of HRSs too is supported by a generous subsidy of 630.000 USD per station.[209]

The second important development concerns the production of natural gas. In the previous decade, 'Beijing pushed its state-owned oil companies to develop shale [gas] in an effort to solve China's reliance on oil imports by creating a domestic alternative by fiat.'[210] Consequently, compressed natural gas (CNG) and liquefied natural gas (LNG) were regarded as attractive fuel alternatives for petrol because of China's relatively rich shale gas reserves and, for some time, the Chinese government invested in these fossil fuels. This resulted in the fact that the share of gas-powered vehicles grew from 0,2% in 2000 to 3,1% in 2014.[211] However, in the early 2010s it became evident that China's production potential was considerably lower than expected. Its shale deposits were much more difficult to extract than was economically viable and this forced China to increase its gas import share. As a result, the government announced in 2015 to reduce shale gas subsidies significantly until 2020.[212]

Natural gas and hydrogen happen to be related in several ways. First, a convenient and cost-effective way of producing hydrogen is through natural gas reforming.[213] Second is that hydrogen and gas share many similarities. Like gas, hydrogen can be transported through gas pipelines as a gasified substance, but it can also be liquefied at very low temperatures, which makes it much more dense and easier to transport over long distances that pipelines cannot reach. This makes hydrogen similar to

[207] Jake Spring, 'China unveils green vehicle subsidy caps; increases technical requirements', *Reuters* (version 30 December 2016) https://www.reuters.com/article/china-autos-electric-idUSL4N1EP27B 31 December 2018.
[208] Sunita Satyapal, 'IPHE Country Update April 2018: The United States', *International Partnership for Hydrogen and Fuel Cells in the Economy*, April 2018.
[209] Cunman, 'IPHE Country Update May 2018'.
[210] Lucy Hornby, 'Beijing plans curbs on shale gas subsidies: Further blow to country's plans to match the US 'shale revolution', *Financial Times* (version 29 April 2015) https://www.ft.com/content/b7d7db78-ee8d-11e4-88e3-00144feab7de 31 December 2018.
[211] Han Hao, Zongwei Liu, Fuquan Zhao and Weiqi Li, 'Natural gas as vehicle fuel in China: A review', *Renewable and Sustainable Energy Reviews* 62 (2016) 521-533, 523, 525.
[212] Lucy Hornby, 'Beijing plans curbs on shale gas subsidies: Further blow to country's plans to match the US 'shale revolution', *Financial Times*, 29 April 2015.
[213] Fuel Cell Technologies Office, 'Hydrogen Production: Natural Gas Reforming', *Office of Energy Efficiency & Renewable Energy* (version 30 December 2018) https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming 30 December 2018.

CNG and LNG as well.[214] Dick de Jongste, CEO of Teesing, explained in an interview that, since the government's decision to cut gas funding, many Chinese stakeholders shifted their interest away from gas and towards hydrogen and FCVs, as hydrogen-related technologies now started to receive generous subsidies.[215]

The fact that the publication of the three hydrogen roadmaps coincided with the government's announcement to phase-out crucial financial support for two other viable alternatives for oil transport does not make it coincidental. Given the despotic and calculated nature of the Chinese government, every single policy or policy amendment reveals a deeper insight about the central government's outlook on a certain strategy. It should therefore not be surprising that many local governments announced comprehensive FCV development policies in the wake of the hydrogen roadmaps. Many cities, including Beijing, Shanghai, Suzhou and Wuhan, published their own ambitious roadmaps, policies, subsidies, R&D programs and pilots. Their goal is to produce thousands of FCVs in the upcoming years and billions of euros worth of annual economic output by 2025.[216]

The fact that local policies echo their central counterparts so blatantly, reveals their conviction that the central leadership regards the development of FCVs as an important strategy. When looking at gas vehicles, the reverse seems more likely. The lowering of shale gas subsidies was preceded by a steep, policy-driven increase in LNG fuel costs, followed-up by bans on various gas vehicles and an announcement by the vice-minister of the Ministry of Industry and Information Technology, expressing that the central government was contemplating a nationwide ban of fossil fuel vehicles altogether.[217] These actions create large degrees of uncertainty and scare off investors. They reveal a strategy that aims to steer relevant stakeholders away from gas and towards the government's preferential direction. In this case new energy vehicles (NEVs).

However, a similar discouragement campaign was launched against PEVs as well. The announcement to phase-out PEV subsidies was not an isolated blow to the PEV industry, but accompanied by other measures that heralded a more difficult phase for PEVs. In December 2017, the central government suddenly threatened to abolish local subsidies in the new Chinese year before continuing them anyway at the last possible moment.[218] The government also raised the technical

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[214] Jörg Gigler and Marcel Weeda, 'Outlines of a Hydrogen Roadmap', *TKI Nieuw Gas/Topsector Energie* (2018), 7, 8, 12, 17, 19.
[215] Teesing is a Dutch company that produces key components for FCVs, HRSs and gas vehicles with extensive working experience in China; Dick de Jongste, 'Interview with Dick de Jongste, CEO of Teesing, conducted by Merijn Drenth', 8 June 2018.
[216] Cunman, 'IPHE Country Update May 2018: China'.
[217] Hao et al., 'Natural gas as vehicle fuel in China', 523, 529; and: *INSIDEEVs*, 'China to Ban 553 Gas Cars Starting Tomorrow' (version 31 December 2017) https://insideevs.com/china-ban-553-gas-cars-starting-tomorrow/ 30 December 2018); and: Yurou, 'Economic Watch: China mulls timetable to ban fossil fuel vehicles, *Xinhuanet*, (version 11 September 2017) http://www.xinhuanet.com/english/2017-09/11/c_136601024.htm 31 December 2018.
[218] Ying Tian, Heng Xie and Yinan Zhao, 'China Plans to Kill Local Subsidies for Electric Cars', *Bloomberg* (version 18 December 2017) https://www.bloomberg.com/news/articles/2017-12-18/china-is-said-to-plan-

requirements for subsidies significantly. This left out the majority of PEV models and currently benefits only a handful of large PEV manufacturers. To make things worse, the government pulled the carpet from underneath various state-owned manufacturers by cutting their funding and selling off their shares.[219] Admittedly, economic and financial considerations play an important role here, as PEV subsidies are getting extremely expensive and should not be wasted on underperforming players.[220] However, it is also a clear indicator that the central government is deliberately strangling a large section of China's PEV industry and signaling to local governments and companies that it is ill-advised to invest in new PEV start-ups and initiatives.

However, the argument that subsidies and other PEV funding are primarily being reduced because of financial reasons is unconvincing. Due to technological progress and the rapid surge in PEV sales, the International Energy Agency and industry research firm Bloomberg New Energy Finance have calculated that PEVs are likely to become commercially competitive around 2025.[221] Until then however, PEVs will continue to rely on financial support and this is illustrated by the fact that even PEV prodigy BYD saw its profits plunge after the government had reduced the height of subsidies in 2018.[222] With the estimated tipping point being so close, it would make no sense for the government to abolish every financial lifeline before the final sprint towards PEV commercialization as it is well-known that policy support is single handedly responsible for virtually all of the current PEV sales in China. If anything, it indicates that the Chinese government has become more skeptical about the benefits of PEVs for China's energy security and that economic motives play a less important role than is often assumed. It is therefore reasonable to assume that policy changes affecting PEVs and gas vehicles were put in place by the government to pave the way for FCV development.

4.2 The "Fuel Cell Vehicle Technology Roadmap"

That FCVs are regarded by the Chinese government as a promising solution to oil imports becomes clear right away. In the introduction of the Roadmap, it is argued that 'the development of FCVs will have significant importance to China's future energy security'[223] and this message is repeatedly

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killing-local-subsidies-for-electric-cars-jbbq58bn 31 December 2018; and: Ying Tian, Heng Xie and Yan Zhang, 'In a Change of Mind, China to Retain Local EV Subsidies', *Bloomberg* (version 12 February 2018) https://www.bloomberg.com/news/articles/2018-02-12/in-a-change-of-heart-china-is-said-to-keep-local-ev-subsidies 31 December 2018.

[219] Yang Jian, 'Beijing turns a big corner: Privatizing troubled automakers', *Automotive News China* (version 8 June 2018) http://www.autonewschina.com/en/article.asp?id=17702 31 December 2018.

[220] Jack Perkowski, 'What China's Shifting Subsidies Could Mean For Its Electric Vehicle Industry', *Forbes* (version 13 July 2018) https://www.forbes.com/sites/jackperkowski/2018/07/13/china-shifts-subsidies-for-electric-vehicles/#1220de9f5703 10 January 2019.

[221] *International Energy Agency*, 'Global EV Outlook 2018' (2018) 61-63, 80; and: *Bloomberg New Energy Finance*, 'Electric Vehicles', 2018. 3.

[222] Adam Jourdan, 'China's BYD warns profit to plunge on electric car subsidy cuts, shares tumble', *Reuters* (version 27 March 2018) https://www.reuters.com/article/us-byd-results-idUSKBN1H31PP 31 December 2018.

[223] Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 1.

expressed throughout the document.[224] For example, in the 'strategic significance' section the emphasis is laid on the multitude of sources that are able to generate hydrogen and the fact that hydrogen has great energy storage potential.[225] Even more interesting is the Roadmap's selective approach regarding rare materials. FCVs are electric vehicles, but differ from PEVs because they use hydrogen instead of batteries to distribute electricity to the traction motor. In order to realize this, the on-board hydrogen must be converted into electricity which is done via polymer electrolyte membrane fuel cells. The electrode catalysts and bipolar plates used in this process are currently made of platinum and graphite, two rare minerals. The latter happens to fulfill a vital function in LIBs as well and is in fact regarded as one of the problematic materials that could threaten the global PEV supply chain.[226] The reason for this is that China produces 67% of all graphite and has the third-largest known reserves.[227] Graphite availability is therefore no issue for China. This is reflected in the Roadmap, wherein graphite plates are not coined as problematic, but as a material whose performance capacities in FCVs should be increased.[228]

However, platinum is clearly referred to as an obstacle and the Roadmap establishes the development of 'low- or non-platinum catalysts and catalytic mechanism[s]' as a top priority for further FCV development.[229] Platinum is very expensive due to its extreme scarcity and highly dispersed reserves and a liability for the government from an energy security perspective, as platinum does not occur in China.[230] Nevertheless, when compared to lithium and cobalt, platinum is much more secure because of China's relatively easy access to Russian platinum. Russia happens to have the world's second-largest platinum reserves, production capacity and importing critical materials from this neighboring is a much more attractive option for the Chinese government.[231] It allows for an overland supply chain that requires a bilateral deal and no involvement of other countries, let alone vulnerable sea-lanes and instable regions. As was mentioned in the first chapter, China's Belt and Road Initiative was established in part to redirect China's flow of oil from sea-lanes to the Eurasian continent. It is therefore safe to assume that the government views platinum as more reliable than lithium or cobalt.

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224 To remind the reader: this concerns the most prominent FCV roadmap, the Fuel Cell Vehicle Technology Roadmap published by the Society of Automotive Engineers of China in 2016 and referred to as 'the Roadmap.'
225 Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 1.
226 Olivetti et al., 'Lithium-Ion Battery Supply Chain Considerations', 232.
227 U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018', January 2018, 72-73.
228 Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 17, 19.
229 Ibidem, 11, 14, 31, 32.
230 South Africa has by far the largest platinum reserves and output in the world; U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018', 124-125.
231 U.S. Department of the Interior and U.S. Geological Survey, 'Mineral Commodity Summaries 2018', 124-125.

However, platinum is so expensive that it is regarded as one of the main obstacles for future commercialization of FCVs.[232] This partially explains the Roadmap's urge to develop non-platinum alternatives. So far, plenty of research has been conducted into synthetic or non-platinum catalysts and results have been fairly positive about the prospects of much cheaper catalysts of carbon, iron and nitrogen.[233] Whether platinum-free catalysts will be introduced in the short run is hard to say, but R&D on low-platinum catalysts has reduced FCV costs with 50% between 2007 and 2018, while quadrupling durability.[234] Whatever the outcome, the Roadmap's emphasis on solving the platinum problem reveals just how important the role of energy security is with regard to the development of FCVs and shows how the Chinese government has taken into account its negative experiences with rare metals in PEVs. This contrasts the content of the Development Plan of Energy-Saving and New-Energy Vehicles Industry' from 2012 (see chapter two), when PEV deployment and the use of LIBs in automobiles was still insignificant and the problematic nature of their supply chain therefore unknown.

One final feature of the Roadmap that deserves attention is that it promotes fuel cell hybrid systems in the early stages of FCV deployment (2020 and 2025).[235] To deploy FCVs with both a LIB and a fuel cell stack makes sense economically. The use of batteries drives down the costs, which allows for a more widespread deployment of FCVs and could lead to economies of scale for FCVs eventually. That, from 2020 onwards, fuel cell hybrids will be the only battery-powered vehicles eligible for subsidies is also interesting. It implies that this is an attempt of the central government to stimulate subsidy-dependent PEV manufacturers and regional governments with battery industries to invest in the FCV and hydrogen sector.

4.3 Fuel cell vehicle initiatives and funding

Unsurprisingly, many of China's first-tier cities have launched plans and policies to stimulate FCVs over the last three years. The scope of their ambitions is becoming visible now that more FCV R&D programs and pilots are being rolled out. Foshan is currently home to the world's largest

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[232] Jan Harvey, 'Analysis: Platinum's fuel-cell car bonanza proves elusive', *Reuters* (version 9 March 2018) https://in.reuters.com/article/platinum-fuelcells-analysis/analysis-platinums-fuel-cell-car-bonanza-proves-elusive-idINKCN1GL1H7 11 January 2019.

[233] Alexey Serov, Kateryna Artyushkova, Ellazar Niangar, Chunmei Wang, Nilesh Dale, Frederic Jaouen, Moulay-Tahr Sougrati, Qingying Jia, Sanjeev Mukerjee and Plamen Atanassov, 'Nano-structured non-platinum catalysts for automotive fuel cell application', *Nano Energy* 16 (2015) 293-300, 294, 298; and: Jianglan Shui, Chen Chen, Lauren Grabstanowicz, Dan Zhao and Di-Jia Liu, 'Highly efficient nonprecious metal catalyst prepared with metal-organic framework in a continuous carbon nanofibrous network', *Proceedings of the National Academy of Sciences of the United States of America* 112 (2015) 34, 10629-10634, 10629, 10634; and: Zhenghang Zhao, Mingtao Li, Lipeng Zhang, Liming Dai and Zhenhai Xia, 'Design Principles for Heteroatom-Doped Carbon Nanomaterials as Highly Effcient Catalysts for Fuel Cells and Metal-Air Batteries', *Advanced Materials* 27 (2015) 6834-6840, 6834, 6839; and: Xiaochen Shen, Changlin Zhang, Shuyi Zhang, Shang Dai, Guanghui Zhang, Mingyuan Ge, Yanbo Pan, Stephen M. Sharkey, George W. Graham, Adrian Hunt, Iradwikanari Waluyo, Jeffrey T. Miller, Xiaoqing Pan and Zhenmeng Peng, 'Deconvolution of octahedral Pt_3N, nanoparticle growth pathway from in situ characterizations', *Nature Communications* 9 (2018) 1-7.

[234] Kendall, 'Fuel cell development for New Energy Vehicles (NEVs) and clean air in China', 118.

[235] Society of Automotive Engineers of China, 'Hydrogen Fuel Cell Vehicle Technology Roadmap', 15.

demonstration pilot with fuel cell buses, while in Shanghai, 500 fuel cell delivery trucks were being launched in January 2018.[236] The most notable pilot can be found in Zhangjiakou, a city near Beijing. This co-host city of the 2022 Winter Olympics is currently materializing a comprehensive network of fuel cell buses, HRSs and a large production plant for fuel cell engines that has to be complete before the Olympics begin.[237] Such a prominent role for FCVs in one of the world's most preeminent sports events demonstrates the importance that the Chinese government attaches to their development.

Another way to measure the importance of FCVs and hydrogen is by looking at China's hydrogen budget. The author of this research did not succeed in finding a specific budget, but in an interview with Bart Biebuyck, executive director of the Fuel Cells and Hydrogen Joint Undertaking, stated that the annual Chinese budget for hydrogen is around two billion euros. This is far more than the annual 250 million euros that the EU and its individual member states spend.[238] Biebuyck's claims are backed by fuel cell expert Michaela Kendall, who writes that 'overall, FCH [fuel cell and hydrogen] technologies look set to be a focus in China, dwarfing investments by other regions including Europe.'[239]

Whatever the precise budget, the message is clear. Hydrogen and FCVs are becoming an increasingly important aspect of China's energy policy and energy security strategy. FCVs do not depend on the electricity grid and can even complement it. Storing the electricity generated from wind- and solar power is very expensive and hard and surpluses of energy are currently being wasted when the demand for electricity is lower than the supply. As was discussed, Plugged-in PEVs are one solution to this problem, but increase security and blackout risks as well. Converting surpluses into hydrogen takes away this problem and due to the fact that compressed hydrogen has a much higher energy and power density than LIBs, it allows for much more efficient long-term storage solutions. These higher density levels also benefit FCVs in another way: range and size. FCVs, are well-known to overrule PEVs and even match ICEVs when it comes to range capacity and this makes fuel cell stacks attractive in general, but in particular for much heavier (military) transport. That this is important to the Chinese is evident when looking at FCV pilots. Most of them involve trucks, buses and even trams. Additionally, FCVs perform much better in freezing conditions than PEVs. This too seems to be important to the government, as many pilots are rolled-out in China's colder regions, like Zhangjiakou where the 2022 Winter Olympics will take place.

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[236] Kendall, 'Fuel cell development for New Energy Vehicles (NEVs) and clean air in China', 117; and: Cunman, 'IPHE Country Update May 2018'.
[237] Xiangmin, 'IPHE Country Update November 2018'; and: FuelCellsWorks, '25 Yutong Fuel Cell Buses Delivered to Zhangjiakou to Boost the Green Winter Olympics', (version 29 August 2018) https://fuelcellsworks.com/news/25-yutong-fuel-cell-buses-delivered-to-zhangjiakou-to-boost-the-green-winter-olympics/ 30 December 2018.
[238] The Fuel Cells and Hydrogen Joint Undertaking is a public-private partnership whose members are the European Commission, the FCV and hydrogen industries and the research community; Fuel Cells and Hydrogen Joint Undertaking, 'Who we are' (version 10 January 2019) https://www.fch.europa.eu/page/who-we-are 10 January 2019; and: Bart Biebuyck, 'Interview with Bart Biebuyck'.
[239] Kendall, 'Fuel cell development for New Energy Vehicles (NEVs) and clean air in China', 117.

These benefits were also mentioned by members of the Chinese delegation during the Sino-Dutch Round Table on NEVs in 2018 (discussed in chapter two), who often addressed the subject of FCVs. Bearing in mind that FCVs only make up a tiny fraction of the Chinese NEV stock, the amount of interest that they displayed towards FCVs was striking. After all, the Chinese state is thoroughly hierarchical and policy decisions are made at the top and followed-up dutifully by policymakers at the lower end. This means that it is unlikely that their interest in FCVs was personal or established independently. The men and women representing China at the round table -some held relatively high positions- were well aware of the growing importance of FCVs in Chinese policy, something that could be distilled from their statements. This was best demonstrated by Jianhua Liu, director of the Shanghai New Energy Vehicle Promotion Office, who not only argued that Chinese policies regarding new energy vehicles would shift towards FCVs, but also stated in his presentation that 'with regard to the current technology trend, we think that fuel cell vehicles will be the future.'[240]

Thus, when taking all of the above into account, this chapter concludes that there has indeed been a notable policy shift from PEVs to FCVs since 2016. That this has largely been the result of the Chinese government's conviction that FCVs are in a better position to address the government's most pressing energy security concern -reducing China's increasing dependency on imported oil- became evident in this chapter to some extent as well. However, in order to fully grasp the impact that energy security considerations have had on this policy shift, it is necessary to integrate and synergize this chapter with this entire research and come to a final conclusion.

[240] Jianhua Liu, 'Remarks by Jianhua Liu, director of the Shanghai New Energy Vehicles Promotion Office', *Sino-Dutch Round Table on New Energy Vehicle Policies* (Shanghai, 12 April 2018).

Conclusion

The importance of energy security to the Chinese government became evident in the first chapter. Here it was argued that a series of historical traumas have fundamentally shaped its attitude towards energy and oil in particular. These experiences established energy security not just as an uninterrupted flow of energy, but as a matter of national security. In the eyes of the Chinese leadership, threats to China's energy security originated predominantly from outside of China.

China's irreversible return to a dependency on imported oil in 1993 has therefore been an alarming development in the eyes of the leadership. In particular, because oil -which used to be crucial to China's military only- has now become a cornerstone of China's internal stability due to the country's growing economy and middle class. The fact that a vast majority of this much-needed oil is produced in instable regions and has to be shipped over vast distances and through vulnerable sea-lanes has made China's oil supply chain its geopolitical Achilles heel and particularly vulnerable to the US navy.

The second chapter argued that it is for this reason that the government started to pursue PEVs from the mid-1990s onwards, as it was convinced that only this strategy could bring down China's consumption of oil. China's primary roadmaps, policies, as well as a thorough study of PEV protectionism and China's battery industry, revealed either explicitly or implicitly how energy security is the primary factor that drives the government's pursuit for PEVs. The sheer financial governmental support that is backing this ambition has illustrated the seriousness of the Chinese government in realizing it.

However, the third chapter showed that PEVs -their batteries in particular- evolved in a way that has significantly undermined their potential of solidifying energy security. The lead-acid batteries that were initially used in PEVs were replaced by lithium-ion batteries (LIBs). LIBs are the only batteries in existence that are capable of realizing large-scale commercialization. However, unlike lead-acid batteries, they contain scarce materials that can only be found in far-flung countries that suffer either from economic or political instability.

Now that the world's transition towards PEVs is accelerating, countries and multinationals are starting to compete fiercely over who dominates lithium and cobalt mines. Up to a point where it is becoming a geopolitical issue comparable to that of the acquisition of oilfields. In addtion, there are serious uncertainties surrounding the impact that millions of PEVs can have on the electricity grid and their meagre potential in cold weather and military applications. When taking into account how the Chinese government perceives energy security, its current dependency on imported oil and the fact that alternative batteries will not replace LIBs anytime soon, there can simply be no other conclusion than that PEVs are unable to solve the dilemma of China's oil import dependency.

This brings us to the fourth chapter, which forms the nucleus of this thesis. This chapter's aim was to identify whether the increasing investments of the Chinese government in FCVs was a reaction to its declining trust that PEVs were able to enhance China's energy security. Striking was that 2016 proved to be a visible turning point. This year witnessed the publication of three important FCV policy documents and the launch of many ambitious FCV pilots on the one hand and a significant decline in policy support for PEVs on the other. Notable as well was that China -lagging behind in FCV development- has now the world's largest budget for hydrogen development by far. Contrasting this is the phasing-out of PEV subsidies, which will not only bring down China's PEV expenditure significantly, but also comes a few years before the estimated commercial tipping point of PEVs globally. A lack of government support in this final sprint could severely damage the progress and competitiveness of its PEV industry. These were implicit, but clear indicators that the government is increasingly devoting its attention towards FCVs at the expense of PEVs, something that was echoed by Chinese officials and experts who show a growing amount of interest in FCVs and, in at least one case, confirmed the government's direction away from PEVs and towards FCVs.

That this has been the result of its conviction that FCVs have a greater potential for energy security became predominantly clear in China's most important FCV roadmap. Herein, the energy security potential of FCVs is repeatedly emphasized and the roadmap's attention for rare materials and its emphasis on FCV performance in cold weather and heavy-duty applications strongly suggests that the document takes into account those aspects that undermine the energy security potential of PEVs. Moreover, a closer look at the key components of fuel cell catalysts did indeed reveal that FCVs appeal much more to the government's notion of energy security than PEVs do.

That energy security is the government's preeminent motive to invest in FCVs also became evident on the basis of the previous chapters. The shortcomings of PEVs as described in chapter three are such an example and so are the similarities that the FCV roadmap shares with prior policy documents that highlight the necessity for PEVs. The framing of PEV development as a strategy to enhance the security of the People's Republic in PEV policies is echoed in the FCV roadmap, as are the highly ambitious production and sales targets that have subsequently been backed by aggressive policies. Another example is the timing of the shift towards FCVs in 2016. This was a few years after LIBs had replaced lead-acid batteries as the dominant PEV batteries and about two years after PEV sales in China had really kicked off. This suggests that the Chinese government had become aware of the downsides of the PEV supply chain around the time that the first FCV roadmaps were published.

The fact that FCVs -like PEVs- are listed under what the government calls ‘new energy vehicles’ (NEVs) also proves that they are foremost regarded by the government as a strategy to reduce China’s dependence on oil import. Combined with the arguments above, it gives rise to the conclusion that PEVs have to a large extent been replaced by FCVs as the Chinese government’s most promising energy security solution to China’s increasing dependence on imported oil since 2016. However, that both FCVs and PEVs are referred to as NEVs also acts as a reminder that the government does not view its transition towards NEVs as a zero sum game between the two options. In fact, diversifying the energy sources of vehicles appeals to a fundamental principle of energy security and that is energy diversification. The prospects of batteries that are devoid of problematic materials might be bleak now, but that does not eliminate the possibility that much more attractive alternatives might emerge eventually. After all, the government has invested largely in China’s battery industry and is not willing to throw it under the bus, something that can be inferred from its development plans for hybrid FCVs. In fact, a small hint of a diversification strategy can be distilled from the emphasis of China’s FCV policies and pilots on cold weather, heavy-duty and long-distance applications. Areas wherein FCVs excel and where the government wants to introduces FCVs first if not foremost.

That being said, FCVs are currently favored by the Chinese government and clearly regarded as a more energy secure solution to oil than PEVs since 2016. This conclusion is important for two reasons mostly. First is the actual impact that this has on China and the world. China is the world’s largest market and producer of vehicles and has been spearheading the development PEVs after the Chinese government decided to throw its full weight behind these vehicles. That the government has recently shifted its interest from PEVs to FCVs does not just mean that China is likely to lead the development of FCVs as well. It means that, all of a sudden, FCVs are likely to play a much more significant role in the global transition from petrol-driven vehicles to future mobility systems than they do now. The sheer size of China’s economy and the government’s control over it make China the most probable place where subsidy-dependent technologies, like FCVs, will reach economies of scale. A sharp increase in FCVs developments and investments in China is therefore likely to lead to an increasing interest in FCVs in the rest of the world. Countries with climate goals might suddenly regard FCVs as an attractive investment option, while global car manufacturers are likely to invest in FCVs to avoid losing their competitive and innovative edge over Chinese companies or losing their foothold in the world’s largest vehicle market.

Secondly, this research and its conclusion have added valuable insights to the literature on energy security, PEVs, FCVs and Chinese energy policy. Prior research that connected PEVs to energy security did not go beyond the observation that PEVs help to reduce oil dependency -as was illustrated by the works of Du and Ouyang, Gong et al. and Liu et al.- and this is mostly because of the importance that energy security literature attaches to traditional energy sources.[241] The focus has therefore been on the electricity feedstock, rather than the battery and this has resulted in an incomplete interpretation of the Chinese government's energy security concerns and the potential of FCVs and PEVs to address this. By studying the influence of key battery materials, such as lithium and cobalt, on the Chinese government's shifting interest from PEVs to FCVs, this thesis demonstrated that these materials have, in fact, a significant impact on energy security. Rare materials should therefore be integrated within the energy security concept instead of being studied separately like Hao et al. suggested.[242]

However, the most important dimension that has been largely ignored by scholars that study FCVs, PEVs and other energy-related policies is perception. The implications of this should not be overlooked and future research on these topics should do well to take it into consideration. Accurately defined by Goldthau, Leung et al. and demonstrated in the historical accounts of Leung et al., Kardon and Yergin, the unique outlook of the Chinese government on energy security has a defining impact on Chinese energy policies and strategies.[243] By using this perception as the starting point of this research, it became clear that FCV and PEV developments and policies in China are as much influenced by the government's ambition to reduce China's dependency on oil imports, as by its desire to avoid supply chains that involve resources, suppliers and shipping routes that the Chinese government has little to no control over. After all, policymakers in Beijing regard an uninterrupted flow of energy as essential to China's prosperity, progress and even stability. Now that China's global importance and influence are growing, the effects of its energy security perception and the policies that originate from it will be felt increasingly as well. Understanding the motives of the world's largest energy consumer and polluter is therefore of crucial importance.

[241] Du and Ouyang, 'Progress of Chinese electric vehicles industrialization in 2015', 530; and: Gong et al., 'New energy vehicles in China', 208; and: Liu et al., 'Critical issues of energy efficient and new energy vehicles development in China', 92.
[242] Hao et al., 'Material flow analysis of lithium in China', 105.
[243] Goldthau, 'The public policy dimension of energy security', 129; and: Leung et al., 'Securitization of energy supply chains in China', 324; and: Kardon, 'Oil for the Lamps of China', 305-328; and: Yergin, *The Quest*, 195-211.

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