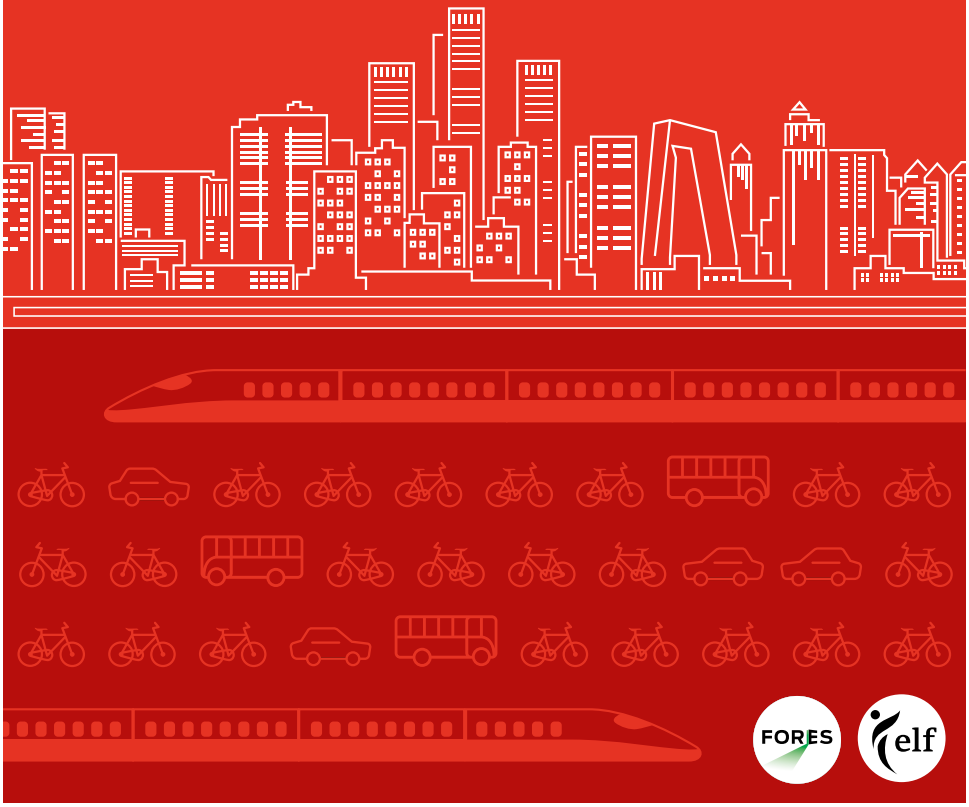
Frank Yang · Mattias Goldmann · Jakob Lagercrantz

Sustainable mobility the Chinese way

Opportunities for European cooperation and inspiration



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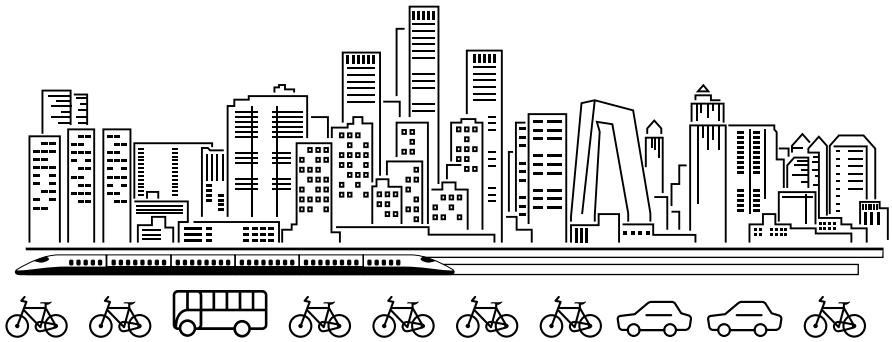

elf FORES

Sustainable mobility the Chinese way
– opportunities for European cooperation and inspiration

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Printed by Exakta Print, Malmö, Sweden, 2018
ISBN: 978-91-87379-45-1

The European Liberal Forum (ELF) is the foundation of the European Liberal Democrats, the ALDE Party. A core aspect of our work consists in issuing publications on Liberalism and European public policy issues. We also provide a space for the discussion of European politics, and offer training for liberal-minded citizens. Our aim is to promote active citizenship in all of this. Our foundation is made up of a number of European think tanks, political foundations and institutes. We work throughout Europe as well as in the EU Neighborhood countries. The youthful and dynamic nature of ELF allows us to be at the forefront in promoting active citizenship, getting the citizen involved with European issues and building an open, Liberal Europe.

Fores – Forum for reforms, entrepreneurship and sustainability – is a green and liberal think tank. We are a non-profit foundation that wants to renew the debate in Sweden with a belief in entrepreneurship and creating opportunities for people to shape their own lives. Market-based solutions to climate change and other environmental challenges, the long-term benefits of migration and a welcoming society, the gains of increased levels of entrepreneurship, the need for a modernization of the welfare sector and the challenges of the rapidly changing digital society – these are some of the issues we focus on. We act as a link between curious citizens, opinion makers, entrepreneurs, policymakers and researchers. The 2030 secretariat, organized by Fores, works for a fossil fuel independent vehicle fleet. Around 80 partners have joined the secretariat based on their belief in the 2030 target, and based on the understanding that the target will be achieved through a combination of a shift to more efficient modes of transport, renewable energy sources and behavioral changes. The 2030 secretariat provides policy input and do continuous follow-ups on the climate target for the transport sector.

We wish to particularly thank the anonymous referees and research editor Annalisa Tulipano for giving valuable feedback on the texts in this publication. All remaining mistakes are completely the responsibility of the authors.

Authors' biographies

Mattias Goldmann has since November 2013 been the CEO of the Swedish green and liberal think tank Fores, which also coordinates the 2030 secretariat for a fossil fuel independent transport sector. Mattias has worked for sustainability and to combat climate change throughout his career, including as the CEO of a climate-consulting firm, spokesperson for an NGO for sustainable transport, information coordinator for one of the parliamentary parties, locally elected politician and lobbyist. Mattias has also lived and worked with these issues for several years in Africa and Latin America. In 2016, Mattias was named Sweden's most influential person in sustainability issues, and in 2017 he was runner-up in Opinion Maker of the Year and knighted by the French government for his outstanding work to combat climate change.

Frank (Xinbing) Yang is Chinese and has been living in Sandviken, Sweden since August 2014. He has been promoting the cooperation between Sweden and China in the areas of cleantech and renewable energy since he founded CleanChina AB in 2016. Frank got his MBA from Beijing's Tsinghua University and has worked with financial institutions such as Bloomberg. He began his PhD research in electromobility at the University of Gävle in February 2018.

Jakob Lagercrantz has long experience in environmental work in Sweden as well as in other countries. He joined the then recently founded Greenpeace Sweden in 1984, and left 11 years later as executive director. Since then, he has worked as an independent consultant, while at the same time devoting time to chairing the NGO Gröna Bilister (the Swedish Association of Green Motorists). In 2013, he co-founded the 2030 secretariat, which currently takes most of his time. Jakob lives on a farm in western Sweden, and drives an electric car with electrons generated from a 120 square meters solar roof.

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Foreword

China: If you can't join them, beat them

It was one of those moments that you can almost reach out and touch. When President Donald Trump stated that the U.S. would withdraw from the United Nations Paris Agreement, the Chinese government immediately stepped forward and clarified that its climate ambitions would not be reduced. Rarely has a change of guard within the world order been so clear, swift and decisive.

Many of us doubted the Chinese. Was this a real conviction or just a shrewd government seizing the opportunity? The early signs are encouraging: the closure of coal-fired power plants has gone faster than what was promised, while solar and wind energy is picking up rapidly, and think tanks around the world estimate that Chinese emissions will plateau and decline faster than the government's pledge. Within mobility, China has become the world's largest market for electric vehicles, shared bicycles, high-speed trains and other important parts of the drive towards sustainability. In many of these areas, it is also the world's largest producer, proving that a strong home market is great for business.

Let's not kid ourselves, the Chinese are not doing this for the climate. That is what I am often told when praising China's initiatives for sustainable mobility. It may be done to improve local air quality and citizen's health, to strengthen the industry's competitiveness or to rebrand China. The more reasons other than climate, the stronger the case for sustainable mobility – in China and around the world.

It is easy for the Chinese: they can decide on a five-year plan and then stick to it. Whilst it is true that long-term targets and incentives are a central part of the Chinese success story – for that is how the country's work on sustainable mobility must be seen – it is also absolutely possible for liberal democracies with recur-

ring multi-party elections to have long term targets. This is proven not least in the area of climate, with the Paris agreement, EU targets and individual member states' commitments, such as Sweden's fossil fuel independent transport sector by 2030, agreed upon by seven of the eight parties in the Swedish parliament.

If you can't join them, beat them. There is much to learn and be inspired by from China's move to electromobility, shared bicycles, high-speed trains and many other areas. All of this may also serve as basis for cooperation: Europe's similar targets and ambitions, as well as industrial know-how and leading research makes us an ideal partner, strengthened by the fact that many European industries are now partially or wholly owned by Chinese interests. But let's not be naive: what we proudly share may soon be used to compete with us. For this reason, cooperation on the basis of mutual self-interest should be seen as the first priority, but combined with a determination to outperform and outcompete when we meet on the market as separate players. The main winner from this approach is local air quality and health, the global climate and future generations. When transport becomes more sustainable, everyone wins. Surely there must be a Chinese character for it.

Mattias Goldmann
CEO of the green and liberal think tank Fores with
the 2030 secretariat for a fossil fuel independent transport sector

Mattias Goldmann

Summary in Swedish

Kina är 2018 års fokusland för 2030-sekretariatet och var i centrum för årets Ekotransport-konferens. Den kinesiska delegationen imponerade på konferensdeltagarna med Kinas snabba omställning inom hållbara transporter: flera av de företag som höll anföranden på Ekotransport existerade inte för bara ett par år sedan, men omsätter nu miljarder yuan och satsar på att inta även den europeiska marknaden.

Samtidigt insåg konferensdeltagarna att mycket av vad som händer inom Kinas skifte till mer hållbar mobilitet och grönare transporter sker av nödvändighet. Luftkvaliteten i många kinesiska storstäder är så dålig att den har blivit ett hinder för ekonomisk utveckling, vilket nu blir en drivkraft för renare mobilitet, ungefär på samma sätt som i Los Angeles för flera årtionden sedan. Men den kinesiska omställningen är inte en kopia av vad västvärlden gjort tidigare, utan många aspekter är unikt kinesiska, på gott och, naturligtvis, på ont. Med respekt för dessa skillnader ser vi fem huvudområden där EU och enskilda europeiska länder kan lära av Kina:

1. **Långsiktiga mål och kontinuerliga anpassningar.** De långsiktiga målen är i huvudsak en följd av Kinas politiska struktur och sättet att arbeta med femårsplaner, men de kombineras med detaljerade, ämnesspecifika planer och kontinuerliga justeringar för att säkerställa måluppfyllelse. Även om detta tillvägagångssätt i stor utsträckning kan karaktäriseras som top-down, innehåller det också element av entreprenörskap som behöver förstås för att fullt ut greppa Kinas utveckling. Denna breda ansats är i linje med vad 2030-sekretariatet funnit vara mest framgångsrikt för en snabb omställning till hållbar mobilitet, och det bör tjäna som inspiration för andra.

2. **Delningsekonomin inom transportsektorn**. I kinesiska städer har delade mobilitetstjänster – som kollektivtrafik, bildelning och cykeldelning – blivit en nödvändighet för en långsiktigt hållbar utveckling. Kina har nu världens största bildelningstjänst som konkurrerat ut Uber, världens största flotta med lånecyklar, och många andra initiativ inom delade transportlösningar. Sammantaget finns mycket att lära för europeiska beslutsfattare på både nationell och lokal nivå: hur man bäst kombinerar delningstjänster med digitala lösningar, hur man säkerställer att en massiv introduktion av lånecyklar utan fasta platser inte sker på bekostnad av fotgängarnas framkomlighet, och hur bildelning verkligen blir en drivkraft för att påskynda omställningen till grönare fordon.
3. **Incitament kopplade till fordonens prestanda.** Den nuvarande kinesiska premien för elbilar och laddhybrider är kopplad till hur lång räckvidden med eldrift är. Om räckvidden är under en viss längd är fordonet inte berättigat till någon ekonomisk stimulans alls, medan elbilar med lång räckvidd får en omfattande premie. Detta påskyndar utvecklingen av fordon som är lämpliga även för konsumenter med ”räckviddsångest” och begränsar den andel av körsträckan som laddhybrider körs på bensin eller diesel, vilket förbättrar luftkvaliteten och minskar klimatpåverkan från dessa fordon. De flesta andra marknader saknar denna stimulansstruktur, och kan i en övergång från generella premier till kvotsystem välja att använda denna typ av prestandabaserade incitament.
4. **Städer som drivkrafter för förändring**. I både Kina och Europa ställs krav på storstäderna att förbättra luftkvaliteten för sina medborgare. Beijing och många andra kinesiska städer inför nu en rad radikala begränsningar av hur bilar får köra i städerna, exempelvis utifrån slutsiffran på registreringsskylten. Det kombineras med incitament för cyklar och eldrivna fordon, där den snabba introduktionen av elbussar i många kinesiska städer imponerar särskilt. I flera europeiska länder skulle större städer ha nytta av en förstärkt och systematiskt verkställd

subsidiaritetsprincip, där besluten fattas på lägsta lämpliga nivå. Det skulle också kunna utgöra en stark grund för ett ökat samarbete mellan kinesiska och europeiska städer.

5. **Elbilskvoter.** I Kina är biltillverkare skyldiga att sälja en viss, ökande andel så kallade New energy vehicles, primärt elbilar. Dessa kvoter är åtminstone i teorin möjliga att handla med, så att det bilmärke som presterar mer än vad som krävs kan sälja sitt överskott till andra tillverkare. Detta system, som liknar det som redan finns i Kalifornien, sänker den totala kostnaden för införandet av elbilar och skapar ytterligare incitament för bilproducenter att prestera över lagkravet. Europeiska länder kan överväga att överge system med subventioner som blir alltmer kostsamma i takt med att försäljningen av elbilar ökar, till förmån för ett kvotsystem av detta slag.

Kina lär sig av Europa

Vi ser också fem huvudområden där kineserna kan lära sig av EU och enskilda europeiska länder som Sverige:

1. **Ställ hållbarhets- och förnybarhetskrav på alternativa bränslen, inklusive el**. I Kina är elen fortfarande till ca 70% producerad av kolkraft, även om andelen sol- och vindkraft ökar ganska snabbt. Här kan Kina ta efter flera EU-länder, som både har en långt högre andel förnybart i elnätet, och ett mycket aktivt arbete på energibolagsnivå för att säkerställa att elbilarna laddas med grön el. Andelen inblandat förnybart bränsle i bensin och diesel är fortfarande mycket låg i Kina, trots att potentialen är mycket stor för att använda restprodukter för både biodiesel och etanol. Här kan Kina inspireras av den reduktionsplikt som bland annat Tyskland och Sverige infört, som ställer krav på bränsleaktörerna att år för år minska klimatpåverkan från bensin och diesel, vilket i praktiken innebär en stegvis höjd andel biobränslen med god klimatprestanda.

2. **Effektivitetsmål och -fokus.** Medan Kina har ett tydligt klimatmål för transportsektorn, är energieffektivitet inte lika starkt i fokus. Målen för energieffektivitet i den 12:e femårsplanen uppfylldes inte[1], och kraven på ökad effektivitet i den nuvarande planen är främst inriktade på att minska kolintensiteten inom energisektorn[2]. Inom detta område kan Kina inspireras av EU och dess medlemsländer, däribland Sverige som ska fördubbla energieffektiviteten per valutaenhet mellan åren 2005 och 2030[3].
3. **Betona och använd nationella/regionala skillnader.** Alla länder har inte samma möjligheter, och alla regioner i Kina har inte samma förutsättningar. Även om delstater som Kalifornien i USA på många sätt har större handlingsfrihet än enskilda medlemsstater i EU, så tillåter och uppmuntrar EU olika strategier mer än vad Kina gör. Det har medfört att enskilda medlemsländer tagit fram lösningar som sedan använts i andra delar av EU, vilket också Kina kan laborera mer med.
4. **Inkludera tunga fordon**. Kina har kommit långt vad gäller att utveckla eldrivna lastbilar, med flera tusen fordon på vägarna – men miljöprestandan hos konventionella lastbilar är inte lika imponerande som EU:s Euro-klassificering och det kommande CO_2-direktivet för lastbilar. Dessutom har enskilda EU-länder, som Sverige, verkningsfulla incitament för användningen av hållbara biobränslen i lastbilar, vilket kan vara relevant för Kina att studera.
5. **Hållbarhetsmål för batterier och biobränslen.** Kina är i framkant vad gäller batterier för elbilar och kan utnyttja denna position för att påskynda omställningen till hållbar produktion. Här ser vi europeiska och amerikanska batteritillverkare som kommit längre med sitt hållbarhetsarbete, inom allt från klimatpåverkan under tillverkningen till arbetsförhållanden i metallbrytningen. Samma sak gäller för biobränslen, där EU:s förnybarhetsdirektiv förvisso har fel och brister, men ändå pekar på hur det nu är möjligt att ställa hållbarhetskrav på förnybart på ett sätt som det fossila inte kan matcha.

1 Radio free Asia, 2013-11-11
2 Reuters, 2016-03-15
3 Regeringen, 2016-11-28

Samarbeta och tävla för gemensamma framgångar

Syftet med denna rapport och 2030-sekretariatets fokus på Kina är att lära av Kinas framsteg, men vi har också sett att det finns områden där Kina kan lära av Europa – vilket i sin tur ökar möjligheterna till ett ömsesidigt gynnsamt utbyte. På vissa områden är det inte uppenbart vem som leder utvecklingen, och här kan Kina och Europa gemensamt driva på utvecklingen framåt – eller välja att konkurrera för att stimulera en snabbare utveckling. Vi ser fem områden där detta är särskilt relevant:

1. **Produktionskapacitet.** Med en snabbt ökande efterfrågan på elfordon – från elcyklar till bilar, bussar, lastbilar, färjor och eventuellt flyget – ökar också efterfrågan på batterier. Många, inklusive Moody's Investment Services rapport från våren 2018, förutspår nu en brist på produktionskapacitet för batterier och/eller enskilda komponenter samt för råmaterial som kobolt, koppar eller nickel[4]. Kina och enskilda EU-länder som Sverige – vars fordonsindustri till stora delar är kinesiskt ägd – kan finna synergier för att påskynda uppskalning av batteriproduktionen, men också för att förbättra återvinningen av befintliga batterier, vilket hittills endast skett i liten skala. Sådana synergier skulle kunna minska de risker för finansiärerna och producenterna som är kopplade till de mycket stora investeringar som behöver göras, men med bibehållen konkurrens för slutprodukterna.
2. **Autonoma fordon.** Konkurrensen är intensiv inom utvecklingen av autonoma fordon, där utvecklingen är minst lika relevant och viktig för tunga fordon, inklusive sjöfart och flyg, som för personbilar. Den kinesiska strategin för artificiell intelligens är imponerande både vad gäller detaljnivå och beslutsamhet, och kan i många avseenden fungera som riktmärke för europeiska ambitioner och för fortsatt konkurrens som vi tror påskyndar utvecklingen.
3. **Affärsmodeller för delad mobilitet**. Kinesiska storstäder är utmärkta utvecklingsområden för delningsekonomi inom transportsektorn,

4 Mining, 2018-05-01

bland annat på grund av den stora befolkningen, den fysiska platsbristen, och att bilägande ännu inte blivit norm. Europa bör, i samverkan eller i konkurrens med Kina, sträva efter att hjälpa företag att utveckla starka och solida affärsmodeller för delad mobilitet, och skapa ekonomiska incitament som uppmuntrar till övergången mot ökad delningsekonomi i transportsektorn.

4. **Grönt flyg.** Kina strävar efter att bli en viktig aktör också inom flyg, och har starka ambitioner för mer hållbart flyg – och utvecklingen mot mer hållbart flyg är brådskande med tanke på hur snabbt flygandet ökar i Kina. Den europeiska flygindustrin kan konkurrera med kineserna inom hållbarhet. Europeiska flygbolag, varav många är statligt kontrollerade, och nationella luftfartsmyndigheter kan ekonomiskt uppmuntra utvecklingen av både hållbart producerade biobaserade jetbränslen och elektrifiering av flyget.
5. **Järnväg.** Sträckor för höghastighetståg planeras, invigs och byggs över hela Kina. Det kombineras med ökad satsning på godståg, inklusive den nyligen invigda godståglinjen mellan Kina och Europa. I flera europeiska länder ser vi också ett ökat intresse för järnvägen, för allt från pendeltåg till nya höghastighetslinjer och godstransporter på järnväg. Kinesiska järnvägsoperatörer är närvarande på flera europeiska marknader inklusive den svenska, och företag som bygger och projekterar järnväg är intresserade av att lägga anbud på sträckor i Europa, inklusive i Sverige. Vi anser att detta kan vara en grund för samarbete för att öka järnvägens andel av de totala transporterna.

Övergripande slutsats: Globalt ledarskap inom hållbar mobilitet kräver mod!

Långsiktiga, konkreta och ambitiösa mål kan vara skillnaden mellan en internationellt uppmärksammad framgång och en medioker utveckling. Kina beslutade 2009 att bli världsledande inom hållbara transporter, och är också på väg att bli det både för eldrivna bilar, bussar och lastbilar samt för delad mobilitet inom

cykling och bilresor. Flera europeiska länder har också som mål att vara globalt ledande i omställningen, och kan visa upp sektorer där ledarskapet redan är etablerat, exempelvis Danmark för cykling, Norge för elbilar och Sverige för biodrivmedel. Men den globala kampen för ledarskap inom hållbar mobilitet har bara börjat, och ju mer intensiv den blir, desto bättre blir den lokala luftkvaliteten och folkhälsan, såväl som det globala klimatet. På många områden skulle Kina och Europa kunna dra ömsesidig nytta av ökat samarbete, medan konkurrens på andra områden kan bli en stark drivkraft för bättre lösningar och minskade utsläpp.

Frank Yang

China's national policies

The challenges

To better understand China's national policies on sustainable mobility, it is relevant to first outline the background, since current environmental degradation and energy safety can be seen as two of the nation's biggest challenges, and are closely linked to transport and mobility.

Economic growth at the cost of environmental degradation

In 2010, China overtook Japan as the world's second-biggest economy[5]. China had already replaced the U.S. as the world's largest emitter of greenhouse gases (GHG) in 2007[6], a position it has maintained since then, with 28.2% of the global carbon dioxide (CO_2) emissions in 2015[7]. This position may be understandable given that China is also by far the world's most populous country, and that many of the products consumed elsewhere in the world are made in China. After two consecutive years of decreasing CO_2 emissions from 2015, Chinese CO_2 emissions increased in 2017 as a result of economic growth and a decline in hydropower[8], although according to some analyses the resumption is believed to be transient[9].

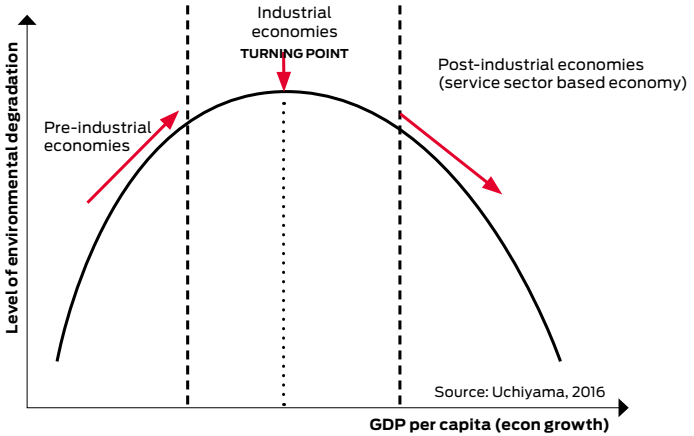
An additional concern is air pollution: 74% of China's 366 cities with real-time air quality monitoring failed to meet national small-particle pollution standards in 2016, according to a Greenpeace East Asia report[10]. The air pollu-

5 BBC News, 2011-02-14
6 The New York Times, 2007-06-20
7 Statista, 2018a
8 Climate Home News, 2017-11-13
9 Phys.org, 2017-11-13
10 Greenpeace, 2017

tion in China is a cause of health problems and shortened life expectancy. For example, the shorter life expectancy north of the Huai River is believed to be caused partly by air pollution, according to the Council of Foreign Relations[11].

Is environmental deterioration an inevitable result of economic growth? What will happen next? Lots of academic work has been done around the relationship between growth and the environment, with the Environmental Kuznets Curve (EKC) hypothesis arguably being the most influential[12]. In brief, it states that economic development initially leads to a deterioration of the environment, but after a certain level of economic growth, levels of environmental degradation are reduced. The EKC hypothesis is illustrated in figure 1 below.

Figure 1. The Environmental Kuznets curve

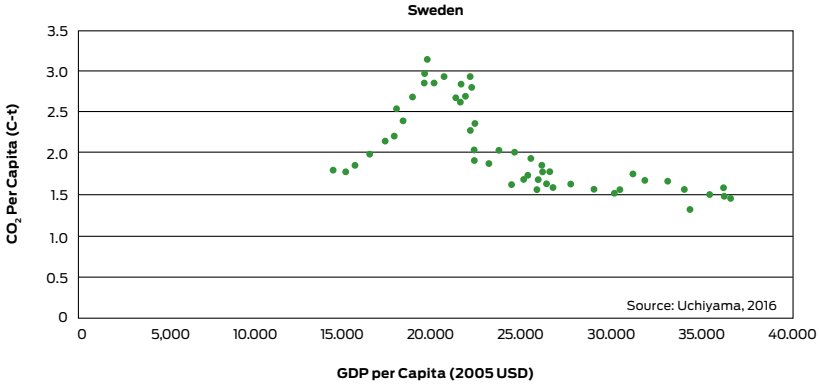


The hypothesis is in line with the development we have seen in many mature economies, including several western European countries, but many also point out that this development is not seen in some of the South-East Asian economies, where local air quality has failed to improve despite economic development[13]. It is also often argued that the model may be of less relevance for emissions where the impact is global rather than directly local[14], such as GHG. Nevertheless, the

11 Albert & Xu, 2016
12 Uchiyama, 2016
13 See e.g. Wong & Lewis, 2013
14 See e.g. Meers, 2000

hypothesis seems to be accurate in some cases, including Sweden, even for GHG emissions, which have declined despite economic growth. For Sweden, this can be seen as a sign of the importance of active policy work to combat climate change – although latest evidence of rising, or at least plateauing, GHG emissions in Sweden puts this correlation into question[15] and underscores the need for additional incentives and legislation[16]. The correlation between Sweden's economic growth, in terms of GDP per capita, and its GHG emissions, in terms of CO_2 emissions, is illustrated in figure 2.

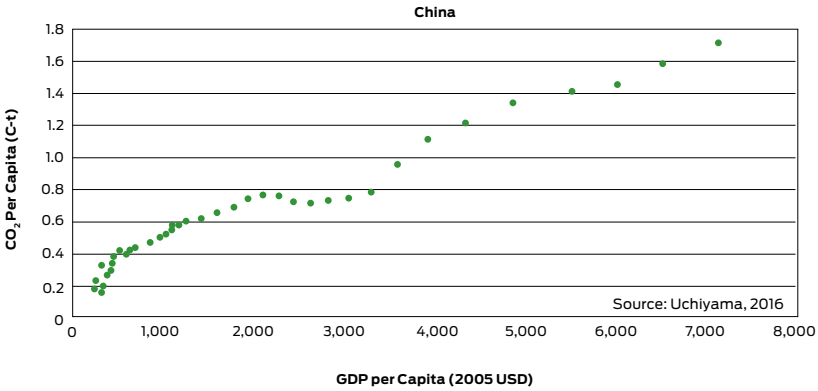
Figure 2. Sweden's Environmental Kuznets curve



China's GHG emissions are, as shown in figure 3, still rising. Whether or not this contradicts the Environmental Kuznets Curve is yet to be determined: the Chinese government has pledged that GHG emissions in absolute terms will decline after 2030[17] at the latest and observers believe that this may happen earlier[18]. To what extent a future decline in GHG emissions would be linked to the rising economic standard will then be a subject for discussion: it may well be a secondary effect from the ambitions to improve local air quality and health, or simply a factor of the rapid global cleantech development and the rapid decrease in price for low-emissions technologies.

15 See e.g. SCB, 2017-10-26
16 See e.g. the 2030 secretariat's indicators for a fossil fuel independent vehicle fleet in Sweden, available at: http://www.2030-sekretariatet.se/indikatorer
17 The Washington Post, 2016-03-07
18 See e.g. Green & Stern, 2017 and MIT News, 2016-02-09

Figure 3. China's Environmental Kuznets curve



China's GDP per capita in 2016 was $8,123, according to the World Bank[19]. At a growth rate of 6.5%, similar to current performance, GDP per capita will double in less than ten years and reach $20,000 in just under 20 years[20]. This would be the level at which GHG emissions should start to decrease if China were to follow Sweden's pattern. There are, however, several reasons to believe that GHG emissions may start to decrease sooner than this, and potentially also faster than in Sweden, once the reduction has been initiated:

- China's Nationally Determined Contribution to the United Nations' Paris Agreement, which China ratified on September 3, 2016, states that China's climate-related emissions are to peak by 2030[21] and influential observers, such as Climate Action Tracker, esteem that "China's policies and actions are set to overachieve [the target]"[22]. With a continued decrease in coal consumption at a pace similar to the past several years, Chinese CO_2 emissions "will decrease substantially up to 2030, reaching the NDC peaking target around ten years early"[23].

19 World Bank, 2018a
20 Our own calculations, based on an annual growth rate of 6.5%
21 Department of Climate Change, National Development & Reform Commission of China, 2015
22 Climate Action Tracker, 2017-11-06
23 Climate Action Tracker, 2018

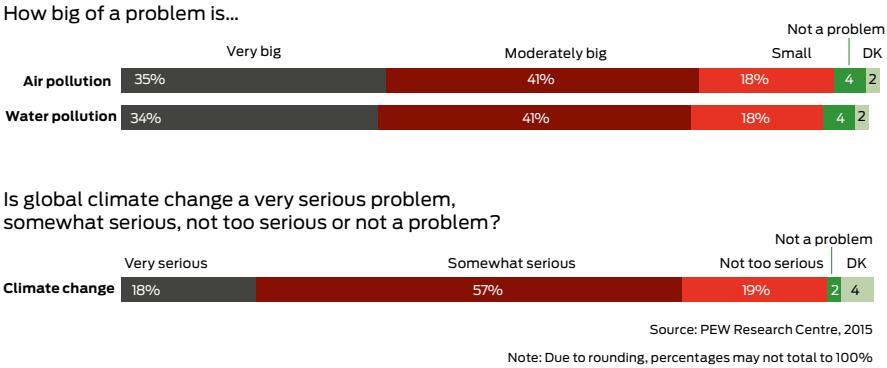
- Local air-quality problems have led to stringent measures in many of the major and most polluted cities, targeting industries, power plants and the transport sector. While the main driver for these measures is to reduce emissions of particulate matter (PM) and nitrogen oxides (NOx), there are also often climate co-benefits[24]. This is the case with, for example, the electrification of vehicles, the proliferation of public transport, and the shift to non-motorized transport, such as bicycles.
- The reduced cost of renewable energy, not least solar and wind, as well as rapid energy-efficiency gains in many sectors of the economy, mean that even in areas where policy is absent or weak, climate-related emissions will likely go down[25].
- Furthermore, but more speculatively, we believe that the Chinese government will over time be more responsive towards demands for reduced emissions from the Chinese population, particularly the emissions that are directly related to health problems. Three-quarters of the persons surveyed see air and water pollution as a big or very big problem[26], as shown in figure 4 below. The number of environmental protests has been increasing at a rate of 30% in recent years[27], which leads the Center for Strategic and International Studies to conclude that "Air pollution in China has turned into a major social problem and its mitigation has become a crucial political challenge for the country's political leadership"[28]. As previously indicated, we further believe that a better control of these emissions will have a strong correlation with reduced climate impact.

Energy security

In 2017, China for the first time surpassed the U.S. to become the world's largest crude oil importer, with 67.4% of oil being imported[29]. At the same time, U.S. oil

24 GHG Online, n.d., and The Guardian, 2015-08-14
25 See e.g. the IEA yearbooks on renewables, the latest to be found at International Energy Agency, 2017
26 PEW Research Centre, 2015
27 Zhang & Yang, 2015
28 As cited by Albert & Xu, 2016
29 China National Petroleum Corp.'s Economics and Technology Research Institute

Figure 4. Views of pollution and climate change in China



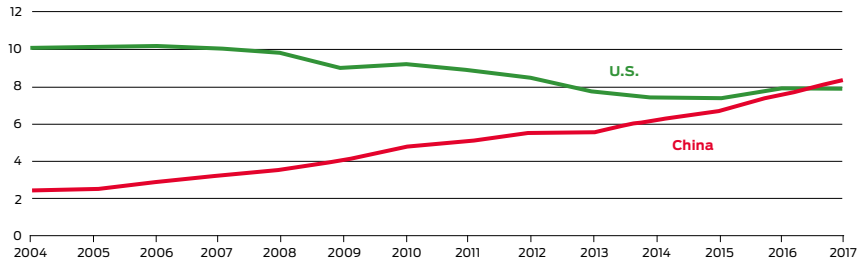
Source: PEW Research Centre, 2015

Note: Due to rounding, percentages may not total to 100%

imports have started to decline[30]. This is illustrated in figure 5 below.

The largest single sector for oil use is road transportation, both worldwide and in China, where demand for oil in the transportation sector reached 46% in 2013, compared with only 30% a decade earlier, according to a Bernstein Research report[31].

Figure 5. Gross crude oil imports in China and the U.S., 2004-2017 (in million barrels per day)

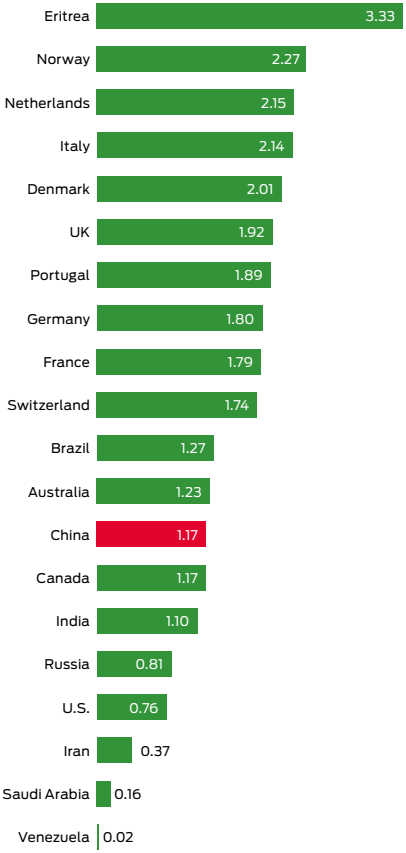


Source: U.S. Energy Information Administration, 2018

30 U.S. Energy Information Administration, 2018
31 Vandana, 2013

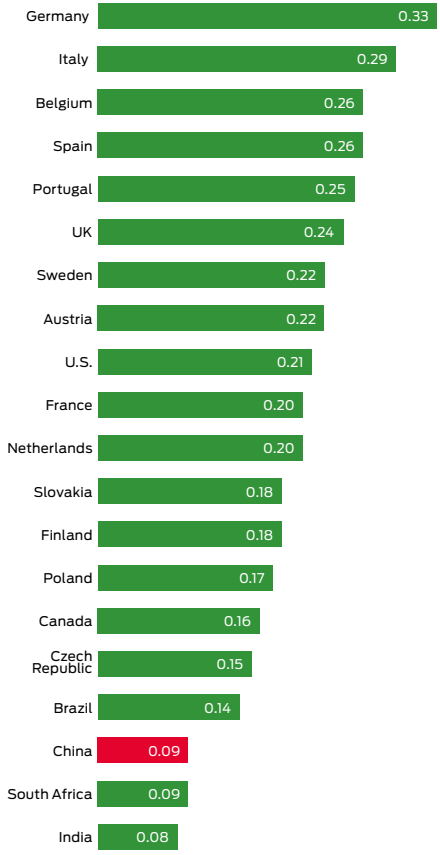
At the same time, there is a surplus of electricity-generation capacity in China, not least from renewable sources. In 2016, the generating hours of thermal power facilities totalled 4,165, with a utilization rate of 47.5%[32]. China's wind curtailment rate – the amount of wind power that could have been generated in existing facilities and used but wasn't – reached 17%, while China's solar curtailment rose by

Figure 6. Petrol prices in selected countries, 2017 (in US$ per liter)



Sources: World Bank, 2017 and Economics Help, 2017

Figure 7. Global electricity prices relative to purchasing power in selected countries, 2017 (in US$ per kilowatt hour)



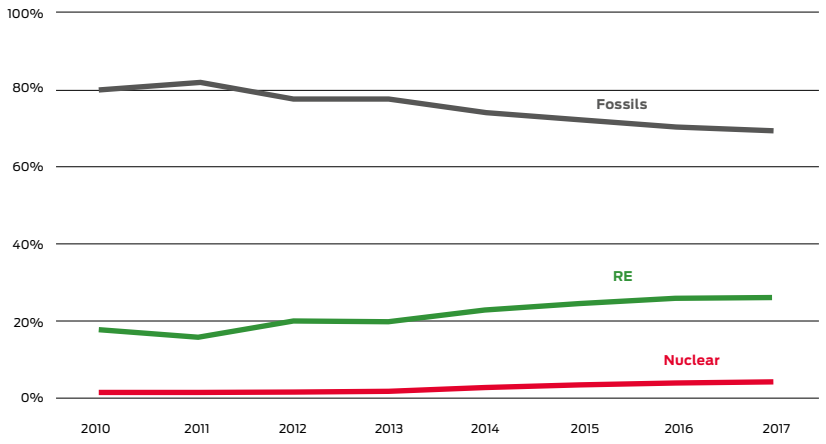
Source: Statista, 2018b

32 China National Energy Administration, 2017-02-03

50% in 2015 and 2016[33]. As a result, petrol prices are relatively higher and electric prices are relatively lower in China, than in other countries. This can contribute as a driver for electrifying the transport sector, since the related energy cost for doing so will be lower than in several other countries. The petrol and electricity prices in China compared with other national markets are shown in figure 6 and 7.

At the same time, China's electricity is getting greener. A large majority of newly installed capacity is renewable, and more than 1,000 coal-powered plants have been decommissioned over the past few years[34]. In 2017, 26.4% of total power generation was from renewable resources[35]. The ratio of renewable electricity will surpass that of coal power within ten years, according to a China Daily report quoting a senior official[36]. While this has not been independently verified, it is in line with several think tank and research organization projections that China will surpass its climate targets[37]. The development of China's electricity mix is shown in figure 8.

Figure 8. China Electricity Generation Mix, 2010-2017



Source: Renewable Energy Institute, 2018, based on data from China Electricity Council and China National Energy Administration. Note: RE means renewable energy.

33 Davies Boren, 2017
34 China Economic Review, 2018-03-02
35 China National Energy Administration, 2018 and Renewable Energy Institute, 2018
36 China Daily, 2017-12-11
37 Forest Trends, 2017-05-15

Can China solve its climate problems?

By embracing a green economy China – as well as other countries – may be able to keep the economy growing, while at the same time reducing reliance on fossil fuels and the consequent emissions.

Provided that the Environmental Kuznets curve is not necessarily accurate for GHG emissions, as discussed earlier in this chapter, there are three ways to escape a worsening environment as economic growth proceeds, according to Taylor and Brock[38]: "One possibility is for technological progress in abatement to lower pollution levels as shown in the Green Solow model; another is intensified abatement as shown by the Stokey Alternative; a third method is to alter the composition of output or inputs towards less pollution-intensive activities."

The so called "green revolution" currently happening in the transport and energy sectors in China may be seen as such an intersection of the three ways, with innovative clean-energy vehicle technologies, policies to promote renewable energy and measures to save energy being introduced at the same time[39].

Green strategies in the 2016-2020 five-year plan

China's five-year plans are used to lay out its longer-term priorities. The focus has been on economic growth, but environmental protection and social progress has also been given attention in the latest plans. The 2016-2020 five-year plan[40] (the 13th FYP) states that "Green is both a necessary condition for ensuring sustainable development and an important way in which people can work to pursue a better life." For the first time, the 13th FYP includes quantified guidance on energy consumption control, stating that China should limit its energy use to five billion metric tons of standard coal equivalent. The target for CO_2 emissions per GDP unit is a reduction of 18% by 2020 compared to 2015. The plan asks to support the development of six emerging industries, including renewable energy and new energy vehicles. Detailed targets are as follows[41]:

38 Taylor & Brock, 2006
39 See e.g. China Electricity Council & China National Energy Administration
40 State Council of China, 2016
41 State Council of China, 2016

Renewable energy

- Make breakthroughs in and promote the industrial application of key technologies such as next-generation photovoltaics, high-efficiency, high-wattage wind power generation, biomass energy, hydrogen power and fuel cells, smart grids, and new types of energy storage devices
- Facilitate the comprehensive utilization of distributed new energy technologies
- Promote the large-scale development of related techniques and equipment

New energy vehicles (NEVs)

- Promote the use of NEVs
- Encourage the use of NEVs for urban public transport and taxi services
- Develop all-electric vehicles and hybrid electric vehicles with a focus on making advancements in key technological areas such as battery energy density and battery temperature adaptability
- Facilitate the development of a network of charging facilities and services that are compatible with each other and come under unified standards
- Improve policies to provide continuous support in this regard
- Ensure the cumulative total production and sales figures for NEVs in China reach five million
- Strengthen efforts to recover and dispose of used batteries from NEVs

The 13th five-year plan to develop strategic emerging industries[42] was published at the end of 2016, as a sub-plan to China's overarching 13th FYP. The document, which is more detailed than the general FYP, combines NEVs, renewable energy and energy saving and environmental protection into one sector and sets a target of an annual turnover of 10 trillion yuan ($1.44 trillion) by the year 2020 for the so-called green and low-carbon sector.

42 State Council of China, 2016

Four key areas within the NEVs industry are mentioned in the plan, namely system integration, battery, fuel cell and charging facilities. Low-carbon development of transportation also appears in the plan. 80% of all China's cities with a population of more than one million are expected to be connected by high-speed railway, which should have a total length of 30,000 kilometers. 3000 kilometers of new urban rail will be built in China's 27 cities with a population of more than three million people[43].

Detailed targets by the year 2020

The 13th FYP to develop strategic emerging industries and the 13th FYP for transportation – which is the sub-plan of the general 13th FYP dedicated to goals for transport and mobility – introduced clear targets for sustainable transport solutions, including NEVs, for the year 2020, as follows[44]:

Yearly production and sales of NEVs	2 million
Stock of NEVs	5 million
Charging stations	12,000
Charging piles	4,8 million
Renewable electric power generation	675,000 megawatts (MW)
Bio-natural gas	8,000 million m^3
Bio-ethanol	4,000 kt
Biodiesel	2,000 kt
High-speed railway	30,000 km
Urban rail	6,000 km

43 Ministry of Transportation, 2017
44 State Council of China, 2017

Frank Yang

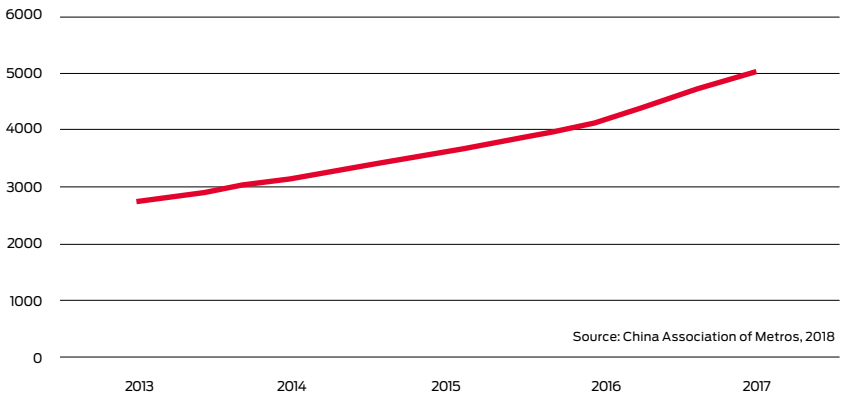
Leading cities and sustainable mobility: Beijing, Shanghai and Shenzhen

As congestion and pollution worsened in most Chinese cities at the beginning of this century, the nation began to promote sustainable transport modes that include public transportation, bicycles and walking. Priority has been given to the public transportation system. In 2009, 13 cities were chosen as pilots to promote NEVs in their public transport fleets, such as buses and taxis[45]. In 2010, the Ministry of Transportation signed a contract with the city of Shenzhen, which is one of the four Tier 1 cities, alongside Beijing, Shanghai and Guangzou[46], to convert the city into a demonstration model of a transit metropolis[47]. A transit metropolis is an urban region with high-quality public transport services and settlement patterns that are conducive to riding public transit[48]. Two years later 14 other cities joined, and now 87 cities are involved. Other pilot projects have taken place as well, with well over 100 cities involved in total[49].

At the end of 2017, there were in total 651,200 public transport buses in China, of which 26.3% were electrified, according to the Ministry of Transportation[50]. In addition to the focus on greener buses, large subsidies have been given to the construction of metro lines, which are all electrified. At the end of 2017, 5,022 kilometers of metro were in service in 34 mainland cities, an 83% increase compa-

45 The Ministry of Finance, the Ministry of Science and Technology, 2009
46 Yicai, 2017-05-31
47 China News Network, 2010-11-12
48 Cervero, 1998
49 China National Energy Administration, 2012-06-11
50 Ministry of Transportation, 2018a

Figure 1. The length of China's metro system, 2013-2017 (in kilometers)



red to 2013, as reflected in figure 1. In March 2018, Shanghai had the largest metro system, with 673 kilometers of track length[51], followed by Beijing's 608 kilometers[52].

Walking and cycling have also been promoted, with the primary aim to resolve the so-called last-mile problem of public transportation in large cities. Six cities were chosen in June 2010 as walking and bicycle transportation system pilots, including Chongqing and Hangzhou. In the third stage of the project, in 2014, 94 demonstration areas were included with 20,900 kilometers of green roads[53]. Green roads are roads with a satisfactory standard of width, gradient, and surface conditions, reserved exclusively for non-motorized modes, i.e. pedestrians and cyclists. This also contributed to the boom of shared bicycles in 2016-2017, described in the in-depth case study on shared bicycles in this publication.

Many cities have now found their own green solutions based on their own endowments. Four of them with distinct characteristics are presented here.

Beijing - the return of bicycles

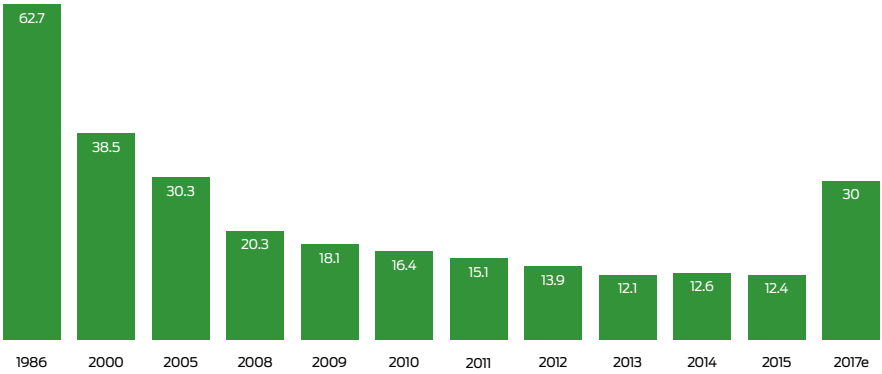
Beijing, like many other Chinese cities, used to be dominated by bicycles which still made up more than 60% of the city's transportation in the 1980s. This is

51 Ministry of Transportation, 2018b
52 Beijing Subway, 2017-12-30
53 Guangming Daily, 2017-08-17

shown in figure 2 below. The ratio dropped as citizens became richer and personal cars became a status symbol. In 2015, only 12.4% of transportation was conducted by bicycle, far below the target of 23% set five years earlier. The same year, the number of private cars reached 4.52 million[54]. The average congestion time was three hours per day and average speed for cars on city roads was 20.9km/h[55]. Cycling was also impacted, as the bicycle lanes were often occupied by cars or used as parking place[56]. The development of the bicycle quota in Beijing's transportation system from the 1980s until today is shown in figure 2.

The Beijing authorities announced in early 2015 that the last Sunday of April is Beijing Bicycle day. In September the same year, the city advised citizens to walk distances within three kilometers, cycle distances within five kilometers and use public transportation for distances within ten kilometers[57]. More importantly, in the *Beijing Development Plan for major facilities during the 13th five-year period*[58], also published in September 2015, the return of bicycles was listed as one of the major tasks to be fulfilled before 2020. The goal for the green transportation ratio in Beijing for 2020 was set at 75%. The ratio, which is a combination of public transportation and cycling, was 70.7% in 2015.

Figure 2. Quota of bicycles in Beijing's transportation system, 1986-2017 (in %)



Data source: Beijing Transport Institute. Note: Public data for 2016 and 2017 is not available. 2017e is the expected quota of bicycles in 2017, according to our own calculations, elaborated on in following paragraphs.

54 Beijing Transport Institute, 2016
55 Beijing Transport Institute, 2016
56 Beijing Transport Institute, 2016
57 Xinhuanet News, 2015-09-21
58 Beijing Municipal Government, 2016

Measures were taken from 2016 to clear and protect bicycle lanes from vehicle encroachment. 965 kilometers of bicycle lanes were cleared and the vehicle invasion rate of bicycle lanes dropped from 18% to 6% by the end of 2017[59].

The return of bicycles has happened earlier and faster than expected, and in a different way. 210,000 shared bicycles from bicycle-sharing companies appeared on Beijing's streets by the end of 2016, and the number grew to 2.2 million one year later, according to statistics from Beijing Traffic Council[60]. This was, to a large degree, the result of private start-up companies using aggressive marketing and venture capital funding. The chapter on shared bicycles has more details on this.

Daily usage of bicycles in Beijing reached six million person times in 2017, 168% more than the 2.24 million of 2015[61]. We can therefore conclude that cycling's share of Beijing transport reached 30% in 2017, though official statistics are not yet available. This is the expected bicycle share for 2017 shown in figure 2 above. In other words, the target of an 18% bicycle transportation contribution by 2020 was already reached by 2017.

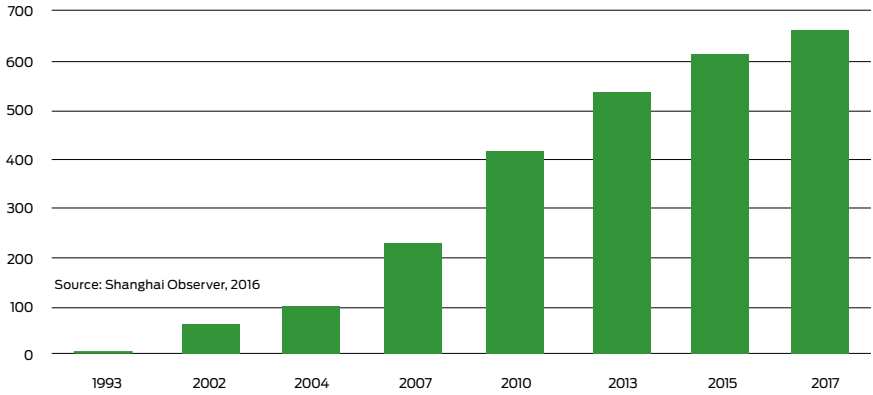
Furthermore, according to the city's 13th FYP for transportation, a network of 3,200 kilometers of bicycle lanes would be ready within Beijing's 5th ring road by 2020 to provide seamless connection to public transportation. This includes what they call the country's first bicycle highway, a two-lane roadway that will be completely dedicated to cyclists, currently being built in the city's northern suburb[62].

Shanghai – metro metropolis

In December 2017 Shanghai, together with Nanjing, became one of China's first two National Transit Metropolis Demonstration Cities[63]. One of the main reasons is that more than 50% of all transport in the city is carried out using public transport, to a large degree thanks to the city's metro system which is used for more than ten million rides daily[64].

59 China News Network, 2017-12-19
60 Beijing Traffic Council, 2018
61 Beijing Transport Institute, 2016
62 Sohu, 2017-10-11
63 Yicai, 2017-12-01
64 Chinese Urban Rail Transit Association, 2018-01-24

Figure 3. Mileage of the Shanghai metro, 1993-2017 (in kilometers)



Shanghai's metro system is the world's largest, 666 kilometers long as of the end of 2017, as can be seen in figure 3. This is the result of a rapid development, since Shanghai had no metro in service until 1993, and in 2004 had only 100 kilometers of metro. Construction accelerated from 2005 to prepare the city for the 2010 Shanghai Expo. During the Expo, 424 kilometers metro lines were in service. Shanghai's metro system was extended after the Expo, but at a slower rate.

One of the city's earliest metro lines is the 29 kilometer-long maglev line that connects Shanghai Pudong International Airport and Longyang Road Station, inaugurated in 2002. The top operational commercial speed of maglev train is 431 km/h, making it the world's fastest train in regular commercial service. It takes less than eight minutes to complete the journey[65].

By the end of 2017, Shanghai had 17 metro lines and 389 stations[66]. The 600-meter coverage rate, meaning the ability to find a metro station within 600 meters from any place in the city, is 75.6%, and the likelihood of finding a bus station within 50 meters and 100 meters from any metro station are, respectively, 75% and 89%[67]. The punctuality rate of the metro system is 98.8%[68]. The total length of operational lines will exceed 830 km by 2020 and 1,000 km by 2030, according to Shentong Metro Group, the subway operator[69]. Automatic trains

65 Shanghai China Tourist Information and Travel Guide, n.d.
66 Ministry of Transportation, 2018-01-04
67 Jiefang Daily, 2017-10-10
68 Jiefang Daily, 2017-12-01
69 South China Morning Post, 2017-12-08

went into service on a 6.7 kilometer-long newly-built metro line in March 2018[70].

Since January 2018, passengers can pay for their tickets by scanning the QR codes that are available in every metro station, using an app downloaded to their mobile phone[71].

Shenzhen – city of electric buses

Shenzhen announced at the end of 2017 that the city had completely electrified its bus fleet, with 16,359 electric buses, making it the first major city in the world that has 100% electric buses for public transport. 8,000 charge points at 510 bus charging stations have been built to charge the buses. It is estimated that the fleet is saving 345,000 metric tons of fossil fuel per year and that the annual CO_2 emissions are being reduced by 1.35 million tons[72].

China's youngest metropolis has been a test field in many aspects, and green transportation is no exception. Shenzhen became one of the first 13 pilot cities for NEVs adoption in 2009, the first transit metropolis demonstration city in 2010, and one of the first eight low-emission demonstration cities in 2011. The city reformed its market-oriented public transportation system in 2007 and began to provide a cost-based financial subsidy to public transportation companies. A fixed subsidy was adopted in May 2013[73]. For example, the subsidy for purchasing a BYD K9, one of BYD:s electric bus models, is one million yuan out of the total cost of two million yuan. Half the purchasing subsidy comes from the central government and half of it comes from Shenzhen city. Furthermore, the city also provides an operational subsidy to cover the operating costs, which can be as high as 0.45 million yuan per bus and year[74] for buses that have completed mileage of 66,000 kilometers[75].

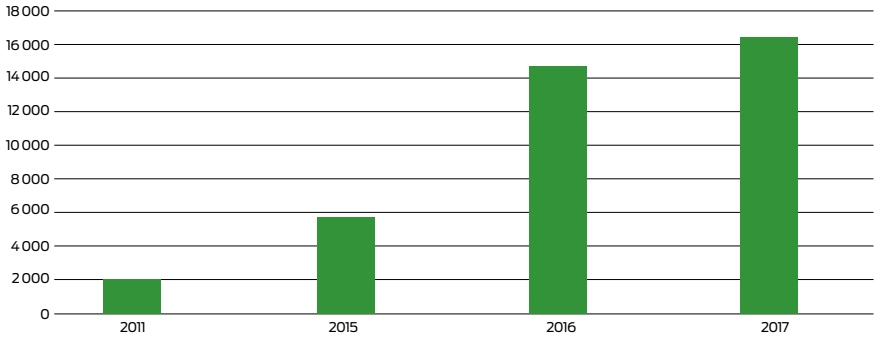
The first batch of electric buses went into operation in 2011, when the 26th Summer Universiade, an international university sports and cultural event which

70 South China Morning Post, 2018-04-01
71 South China Morning Post, 2018-01-18
72 China Urban Planning Network, 2017-12-28
73 Shenzhen Bureau of Public Transportation, 2017
74 Shenzhen Finance Committee, Shenzhen Transportation Commission, 2016-04-27
75 Ding & Huang, 2017

is held every two years in different cities, was held in Shenzhen. Mass adoption began in 2015, when the local government required that at least 70% of newly purchased buses should be electrically powered. 9,726 electric buses were adopted in 2016, pushing the electrification rate of the city's bus fleet to 90%[76]. The increase in electric buses in Shenzhen between 2011-2017 is shown in figure 4 below.

80% of Shenzhen's electric buses are provided by the local producer BYD[77]. The city is also home to several other major players in China's EV value chain, such as battery producer Optimum and EV producer New Flyer. That is also part of the reason why Shenzhen aims to completely electrify its taxi fleet by 2020. At the end of 2017, there were 12,518 electric taxis in the city, accounting for 62.5% of the taxi fleet[78].

Figure 4. Number of electric buses in Shenzhen, 2011-2017



Source: The Paper, 2017-12-28

Hong Kong's public transportation system

Apart from focusing on these three cities, we will also take a brief look at Hong Kong's public transportation system, which was named the world's best in 2017 by Arcadis' *2017 Sustainable Cities Mobility Index*[79]. We do this using a personal story from a Hong Kong tourist about the experience of traveling by public transport in Hong Kong.

76 The Paper, 2017-12-28
77 Clean Technica, 2017-11-12
78 The Paper, 2017-12-28
79 Forbes, 2017-10-30

A journey with Hong Kong's public transport system

Punctuality, low prices and a unique business model are some of the reasons behind Hong Kong's public transportation system being named the world's best in 2017.

Traveling to a new city can invariably be exciting, but a journey by public transport in a new location can sometimes be the opposite. How do you pay for the ticket? Which modes of transport are available? What's the next station?

Hong Kong's public transportation system was voted the world's best last year, and some of the reasons for this are outlined below.

Clear communication

The city of Hong Kong has about seven million inhabitants, i.e. about seven times the populace in Greater Stockholm. Nevertheless, the subway – and the entire public transportation system – works in an efficient and user-friendly way.

On each street you will find a sign pointing to the nearest metro station. At the station, you will find several simple communication techniques that make the subway easy to use even for tourists: the escalators use both sound and light to signal the direction they will take you, there are arrows in walkways and stairs that explain which side to keep to, the turnstile to enter the platform tells you how much money is left on your travel card, and there are arrows in the floor by the platform doors telling you where to stand as you wait to board, to leave as much space as possible for those who want to get off the train.

Once on the train, there is a station map with a lamp at each station which, by blinking, tells you both what the next station is and – if you got on the train in a hurry and need to know what train you are actually on – the direction in which you are currently traveling.

Broader business model

The card you use to pay for your trip is called an Octopus card and is topped up at vending machines or a 7-Eleven. The Octopus system is one of the MTR's (Mass Transit Railway) brands, and not just used as a means of payment on public transport. At the 7-Eleven, where you might just have topped up your card, you can also pay for the coffee with your Octopus card. If you should decide to drive a car, you can pay for your parking with the same card, and the system is also sold to third parties as a general-access system for car parks or apartment buildings.

Buildings are also within the MTR's field of familiarity: a number of malls and skyscrapers in Hong Kong have been built and are owned by the MTR, and real-estate development is actually its largest source of income. The subway itself is actually secondary, although the MTR is behind not only Hong Kong's but also parts of Britain's, Australia's and Sweden's counterparts.

High profitability

The Hong Kong metro has a 99.9% punctuality rate and more than five million travellers on an average day. The Hong Kong's public transportation system is also one of the world's most profitable. Ticket revenue covers 187% of the operating costs of the system[80], with ticket prices within the range of about HK$3.50-7.50 (approximately US$0.63-0.95).

The Hong Kong citizens also seem to have great trust for their public transport in general and the metro in particular – the pace of walking tunnels and stairs is calm and sensible, and people rushing through closing doors seems to be a rare event. They seem to know that ice and leaves on tracks creating delays, and the hour-long minutes that seem to occur only on the very coldest days of the year, are nothing but stories from far-away countries.

80 The Straits Times, 2015-10-29

Frank Yang and Mattias Goldmann

In-depth case study: Electric vehicles (EVs)

Introduction

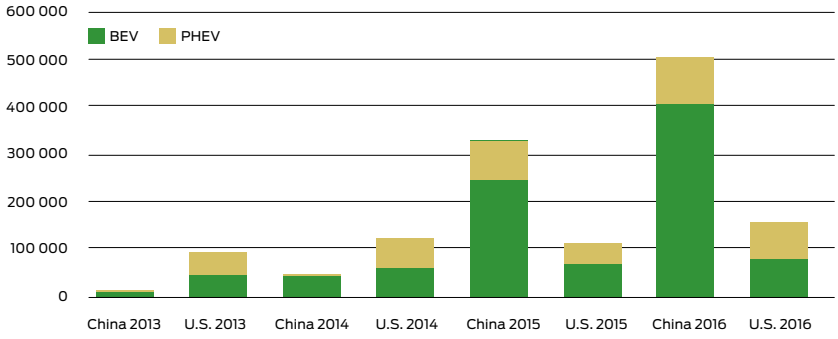
New energy vehicles (NEVs) are one of the strategic emerging industries listed in China's five-year plan for 2016-2020[81]. The term NEV is normally used in China to designate plug-in electric vehicles eligible for public subsidies, and includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel-cell electric vehicles (FCEVs). While China's government does not have any clear policy preference between the different technologies, the market uptake and the public discussion has, until now, been mainly on BEVs, particularly on the passenger car side. FCEV is still in the initial stage of industrialization, and the high cost and lack of infrastructure are aspects that are hindering the adoption of FCEVs.

China decided to support the development of NEVs in 2009, in the current five-year plan by that time, but little progress was made until late 2013, when the government announced that it would subsidize carmakers for the electric vehicles they sold[82]. In 2015, China became the world's largest market for electric cars, ahead of the U.S., which was the largest market until that time. This can be seen in figure 1 below, which also shows that sales of new BEVs and PHEVs on the Chinese market totalled just above 500,000 units in 2016. Registrations of NEVs reached 1.5% of total car sales in China in 2016. The same number for 2017 was 2.1%, which is above the levels for both the U.S. (1.2%) and Europe (around 1.9%).

81 The National People's Congress of the People's Republic of China, 2016. Outline of the 13th five-year plan for the National Economic and Social Development, Chapter 23.
82 National Development and Reform Commission, 2016a

In 2017, the Chinese market for plug-in electric vehicles (PEVs) represented roughly half of the 1.2 million PEVs sold worldwide. In 2017, Chinese carmakers made 47% of all PEVs sold globally[83]. In 2018, the market share for EVs in China is expected to be 3%[84]. At the end of 2017, the total number of NEVs in use in China was 1.53 million, according to statistics from the Ministry of Public Security[85].

Figure 1. Sales of BEVs and PHEVs in China and the U.S., 2013-2016



Source: EV Volumes, Electric Vehicle Sales Data, 2017. Note: Numbers include passenger cars and commercial cars

The current market for new energy vehicles (NEVs)

Vehicle sales

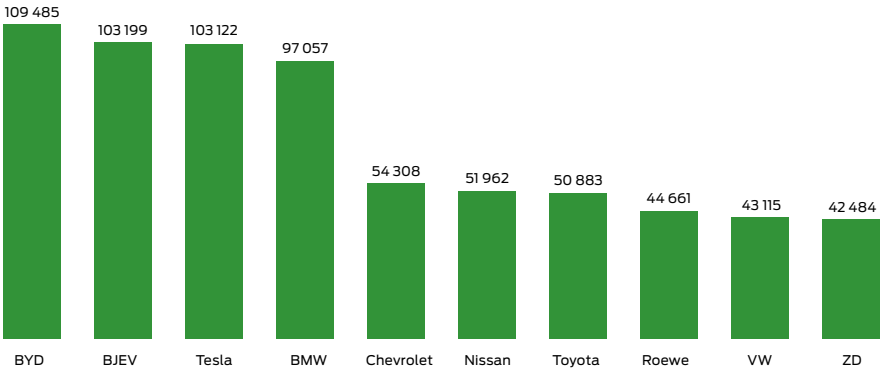
Sales of BEVs and PHEVs (passenger cars only) in China grew 72% between 2016 and 2017, to 579,000, according to Business Insider Australia[86] (however, according to EV Volumes, the number of BEVs and PHEVs was 605,500 in 2017[87]). At the same time, sales outside China were 540,000, which means that more than half of the world's new BEV and PHEV passenger cars in 2017 were sold in China. Compared to the global market growth at 34%, Chinese growth was substantially stronger than the world average. Business Insider Australia also reports that the

83 CleanTechnica, 2018-01-29
84 EV Obsession, 2018
85 China News Network, 2018-01-15
86 Business Insider Australia, 2018-01-22
87 EV Volumes, Electric Vehicle Sales Data, 2018

increase in market share of EVs was larger in China – 2.3%, up from 1.4% – compared with the rest of the world, where it was 1.4%, up from 1.1%[88].

The Chinese BEV and PHEV market is dominated by national producers, with BYD Auto topping the list of plug-in passenger car sales with 109,485 vehicles sold, before BJEV, which jumped to second place from fifth in 2016. The top-selling EV brands are shown in figure 2 below, with BYD, BJEV and ZD being Chinese brands. BJEV also had the bestselling individual model, called the EC, followed by Tesla's Model S[89]. The top-selling EV models and their market share in 2017 are shown in figure 3 below.

Figure 2. Top passenger EV companies by brand sales, 2017



Source: Ali Auto, 2018-02-01

Figure 3. Global top passenger EV sales by model, 2017

Rank 2017	Model	Sales 2017	Market share %	Rank 2016
1	BJEV EC	78,079	6	42
2	Tesla Model S	54,715	4	2
3	Toyota Prime	50,830	4	64
4	Nissan Leaf	47,195	4	1
5	Tesla Model X	46,535	4	7
6	ZD D2	42,342	3	32

Source: Ali Auto, 2018-02-01

88 Business Insider Australia, 2018-01-22
89 Ali Auto, 2018-02-01

Battery production

In 2017, the overall installed capacity of EV and PHEV battery production in China reached 36.2 gigawatt hours (GWh), up 29% from 28 GWh in 2016, according to Shenzhen Gaogong Industry Research Co., Ltd (GGII). The biggest manufacturer was Chinese CATL, with a total installed battery production capacity of just under 10.6 GWh, nearly 30% of China's overall industry capacity. It was followed by BYD Auto, with an annual installed capacity of almost 5.7 GWh. In terms of battery type, lithium-iron phosphate (LFP) batteries took up 50% of 2017 power battery deliveries, ternary lithium-iron batteries 45%, while lithium-manganese spinel (LMO) and lithium titanate (LTO) represented 4% and 1%, respectively, of the total deliveries[90].

Charging facilities

The number of public charging points for electric vehicles in China grew by 51% year-on-year to 214,000 in 2017, and just over double that, around 450,000, if private charging points are counted. Over 110,000 electric vehicle charging poles have been installed in Beijing alone[91] and over 40% of Beijing's residential areas are equipped with charging facilities[92]. This gives China the largest number of public NEVs charging stations in the world, with a ratio of EVs to charging point as high as 3.8:1[93], which is relatively high compared to other countries. For example, Sweden currently has a ratio of 0.10:1[94].

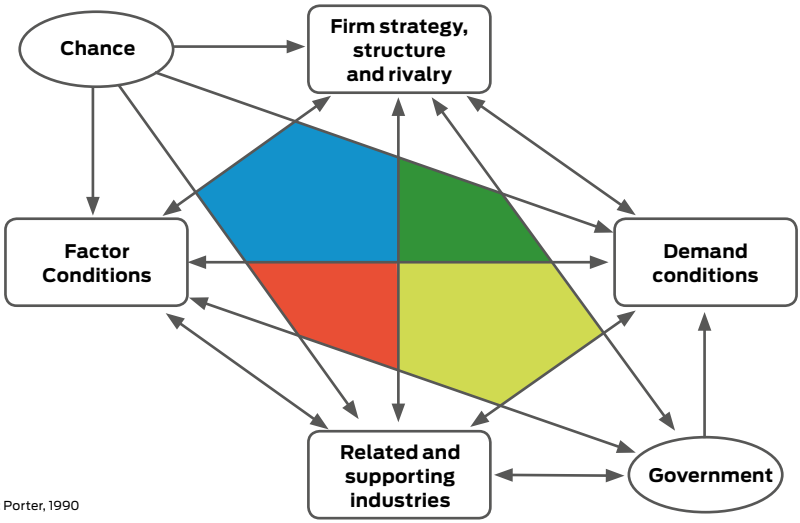
The climate benefits of BEVs and PHEVs depend, to a large degree, on how they are charged, with a simulation of Beijing in 2020 showing that slow charging can result in effective emissions reductions, while fast charging may be counterproductive since it puts high demand on the electricity grid and on power production[95].

90 Shenzhen Gaogong Industry Research Co., Ltd (GGII), 2017
91 Beijing Municipal Commission of Housing and Urban-Rural Development, 2016
92 China Daily, 2018-01-11
93 Xinhuanet News, 2018-01-21
94 Power Circle, 2018-05-07
95 Chen, 2018

A deeper look at China's EV industry using Porter's diamond model

Professor Michael Porter[96] puts forward a dynamic model of international competitiveness, explaining why some industries in a country will be strongly competitive on the international market, and sums up the four factors that can affect the competitiveness of a country's industries; namely, (i) factor conditions, (ii) related and supporting industries, (iii) demand conditions, and (iv) firm strategy, market structure and competitors. Besides the four factors, there are two other elements, namely (v) government policy and (vi) chance events, that can influence the diamond. These factors and elements "interact with each other to create conditions where innovation and improved competitiveness occurs"[97]. We will use this model to analyze the forces behind the fast growth of China's EV market.

Figure 4. The Porter diamond model



Source: Porter, 1990

96 Porter, 1990
97 Traill & Pitts, 1998

(i) Factor conditions

Porter defines factor conditions as human resources, physical resources, knowledge resources, capital resources and infrastructure. An industry often has specialized resources, which are important for its competitiveness[98].

Natural resources

Lithium: Lithium-ion batteries are currently the most widely used in plug-in electric cars globally[99]. China has among the highest lithium reserves in the world, according to *Lithium Today*[100]. China's lithium reserves in 2017, compared to other countries, is shown in figure 5 below. 77% of the lithium resources held in the country are to be found in The Qinghai salt lakes in western China. Despite commercial investments, however, there has been no significant lithium production from this source. This can be explained mainly by the fact that lithium sources in South America are more favorable due to their chemistry[101]. Thus, even with its reserve mass[102], China only contributed to 7% of the world's lithium production in 2017[103]. At the same time, China is globally the largest lithium consumer, in large part because of its EV industry[104].

Graphite: Besides lithium, lithium-ion batteries for EVs also require two electrodes: a cathode, usually made with metals such as nickel and cobalt, and a graphite anode[105]. In 2016, China had the world's largest graphite production, with a yearly production of 780,000 metric tons[106]. According to the U.S. Geological Survey[107], the country accounted for 66% of world graphite production last year, and 35% of world consumption.

Rare-earth metals: There is an increasing demand for rare-earth metals that can be used in electric vehicle motors, in which typically neodymium and praseodymium are used. In 2016, China's rare-earth industry produced 105,000 metric

98 Porter, 1990
99 Mok, 2017
100 Lithium Today, 2017
101 Lithium Today, 2017
102 Investing News, 2018
103 According to our own calculations, based on China's lithium production compared to the total world lithium production
104 Lithium Today, 2017 & Investing News, 2018
105 Buqa et al, 2005
106 Investing News, 2017
107 U.S. Geological Survey, 2017

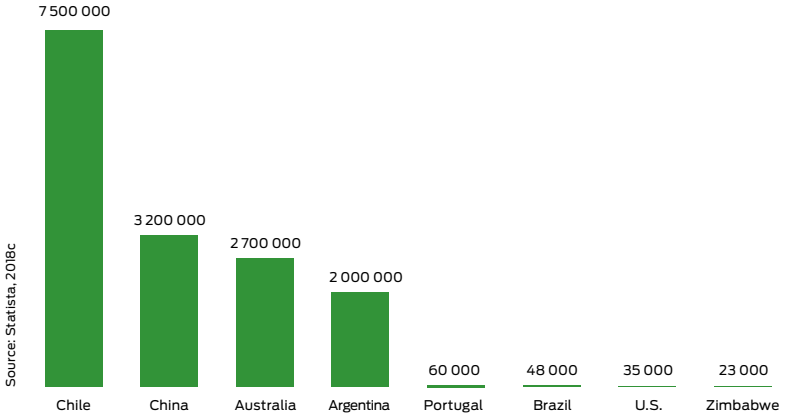
tons of rare-earth metals, which makes the country's rare-earth industry the largest in the world[108].

Labor, capital and infrastructure

China ranks in the top third globally in terms of human capital (which is a measure of the economic value of a worker's skills and attributes), according to the *Readiness for the Future of Production Report 2018* by the World Economic Forum[109], though the notion of Chinese labor as cheap is now only partially true, and very dependent on the countries with which it is compared. Chinese factory workers were in 2016 on average paid $3.60 per hour, up 64% from 2011, according to market-research firm Euromonitor[110]. This is more than five times the average hourly manufacturing wage in India, but still around 35% lower than wages for factory workers in developed markets[111].

China is also rich in venture capital. In 2016, a decade-long Chinese venture-capital boom reached $50 billion in firm commitments, for the first time almost matching the U.S.[112]. The EV industry is seen and marketed as a good destination for venture capital and other types of investments, with 450 billion yuan (cor-

Figure 5. Countries with the largest lithium reserves worldwide, 2017 (in metric tons)



108 Bohlsen, 2017
109 World Economic Forum, 2018
110 CNBC, 2017-02-27
111 Zhang, 2014
112 Venture Beat, 2017-10-14

responding to approximately $70 billion) invested into 70 electric vehicle projects in 2017[113].

China has invested a lot in its infrastructure over the past decades. According to the BBC[114], China spent 8.6% of its GDP between 1992 and 2013 on the construction of roads, railways, seaports and other transport infrastructure, compared to 2.5% for western Europe, and the same figure for the U.S. and Canada together.

(ii) Related and supporting industries

According to Porter, "Related and supporting industries can produce inputs that are important for innovation and internationalization." "These industries provide cost-effective inputs, but they also participate in the upgrading process, thus stimulating other companies in the chain to innovate."

Having surpassed the U.S. in 2010, China's manufacturing sector is now the largest in the world, with a total global Manufacturing Value Added (MVA) of close to $3 trillion in 2016, representing approximately one-quarter of the global MVA[115]. While China is a leader in terms of the scale of its production base, what is being produced is still not as complex as in leading developed nations: China ranks as the world's 26th most-complex economy[116]. China's auto-parts industry is not an exception. There are over 10,000 Chinese factories supplying automobile parts[117], but only a few of them can produce complex key parts for internal combustion cars, such as engines and gear boxes. Such parts are only available from foreign companies or their joint ventures with local Chinese companies. The key parts for EVs, such as batteries, motors and electric control-system products can however be produced by local suppliers[118].

(iii) Demand conditions

"Demand conditions in the home market can help companies create a competitive advantage, when sophisticated home market buyers pressure firms to inno-

113 China Association of Automobile Manufacturers, 2017-12-08
114 BBC, 2016-06-20
115 World Economic Forum, 2018
116 Center for International Development at Harvard University, n.d.
117 Forward Industry Research Institute, 2017
118 China National Energy Administration, 2017-01-16

vate faster and to create more advanced products than those of competitors." (cited from Porter, 1990)

China has remained the world's largest automotive market since 2009. A total of 28.88 million cars were sold in 2017, including 24.72 million passenger cars[119]. While this is due to the fact that, over the last decade, many more Chinese have become owners of passenger cars, the rate of motor vehicles per capita is still at a relatively low level compared to for example the U.S.[120]. This means that there is still much room for demand increase, or – depending on policy – room for alternative routes for the future, where public transport, shared mobility and other solutions take a larger share of total mobility.

Current projections from China's Ministry of Industry and Information Technology[121] are that new car sales will reach 35 million in 2025. Of these, 20% should be NEVs, in line with the short-term target of 8% for 2019 and 10% for 2020, as announced by the Ministry of Industry and Information Technology[122].

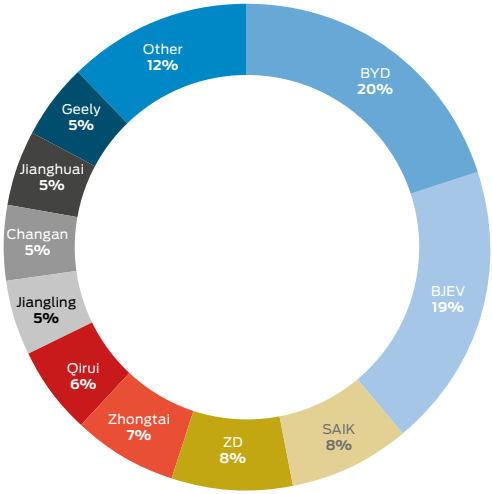
(iv) Firm strategy, market structure and competitors

"Firm strategy, structure and rivalry constitute the fourth determinant of competitiveness." "The way in which companies are created, set goals and are managed is important for success." "But the presence of intense rivalry in the home base is also important; it creates pressure to innovate in order to upgrade competitiveness." (cited from Porter, 1990)

There are hundreds of EV manufacturers that are producing thousands of car models in China. Only those that meet certain requirements can be listed on the Ministry of Industry and Information Technology's recommendation list and are eligible for incentives. 3,233 vehicle models from 224 companies are on the 2017 version of the list[123]. Yet 88% of the market is dominated by the top ten manufacturers, with the top two taking around 20% each. BJEV sold the most battery EVs, while BYD Auto had a focus on plug-in hybrid EVs[124]. In figure 6, the market

119 Data from China Association of Automobile Manufacturers
120 Wang et al., 2011
121 Ministry of Industry and Information Technology of the People's Republic of China, 2017
122 Securities Times, 2018-03-09
123 CN Auto News 2018-01-04. Original data from Ministry of Industry and Information Technology
124 Online Car Market, 2018-01-16. Original data from China Passenger Car Association

Figure 6. Market shares of NEVs companies in China, 2017



Source: Online Car Market, 2018-01-16. Original data source: China Passenger Car Association. Note: Foreign NEVs companies are represented in "Other".

share for different EV manufacturers in 2017 is shown. As can be seen in the chart, the domestic market is dominated by Chinese manufacturers. 19,186 BEVs were imported in 2017, with 16,727 of them being from Tesla[125]. China lowered tariffs on imported cars from 25% to 15% in May 2018, which might slightly change the situation towards a higher number of imported cars – however, the tariffs are still relatively high compared to other countries[126].

(v) Government

"Government can influence each of the above four determinants of competitiveness." "Clearly government can influence the supply conditions of key production factors, demand conditions in the home market, and competition between firms." "Government interventions can occur at local, regional, national or supranational level." (cited from Porter, 1990)

Subsidies from central and local departments are currently playing a vital role for the development of the emerging EV industry in China, as well as on other markets. The Chinese government first decided to support the development of NEVs in 2009 and started to provide a purchase-incentives pilot in 2010, with a

125 D1EV, 2018-01-30
126 New York Times, 2018-05-22

governmental subsidy being paid to the car seller. The latest incentive plan for purchase of NEVs, shown in figure 7 below, was published in April 2015[127].

Figure 7. Purchasing incentives for NEVs (in thousand yuan)

	Electric range, km	2016	2017	2018	2019	2020
BEV	100 - 150*	25	20	20	15	15
BEV	150 - 250	45	36	36	27	27
BEV	250 +	55	44	44	33	33
PHEV	50 +	30	24	24	18	18

Source: Ministry of Finance, 2016. *Note: From June 12, 2018, there will be no incentives for BEVs with a range below 150 km[128].

There are three characteristic traits of the Chinese incentives for electric cars:

1. **The subsidy is range-related – up to 250 km.** BEVs with a range of less than 100 km do not qualify for any subsidy, while at the other end of the scale, there is no added incentive for BEVs with a range of more than 250 km.
2. **Plug-ins generally get less support**, and low-range PHEVs get nothing. While on some markets, BEVs and PHEVs are treated equally (until June 30, 2018, this included Sweden, where BEVs and PHEVs were considered "super-environmental cars"[129]), in China the PHEV support is substantially lower, and most PHEVs – with an electric range of under 50 km – fail to qualify.
3. **The subsidies will be reduced.** Early buyers of BEVs and PHEVs have received a government bonus about two thirds larger than the buyers in 2019-2020, and from 2019, the subsidies are partly replaced by demands on car manufacturers.

In addition to this, NEVs are exempted from the 10% purchase tax on new vehicles, with a maximum total financial incentive per vehicle of 60% of the vehicle's price. To get the tax exemption, purchasers must choose from a list of vehicle

127 National Development and Reform Commission, 2016a
128 Xinhuanet News, 2018-02-27
129 Transportstyrelsen, 2018

models decided by the Ministry of Industry and Information Technology. The list is updated continuously, and the EV models that are included in the list vary[130].

In 2017, the exemption from the purchase tax was extended to the end of 2020, the same end-year as for other incentives[131]. The subsidies are to be replaced with a so-called dual-credit system for NEVs, starting from April 2018[132]. Under this system, car manufacturers responsible for introducing more than 50,000 cars per year to the Chinese market will have to reach 8% NEVs credits in 2018, 10% in 2019 and 12% in 2020. One NEV is calculated as two to five credit units, depending on its electric range. Manufacturers who fail to meet the goals will have to buy credits from other manufacturers, or receive a fine[133].

In addition to the central incentives, local governments will normally provide incentives as well, both financial and non-financial. For example, EVs were exempted from Beijing city's licence plate lottery in 2011[134]. In Beijing, you have to obtain a license plate through the lottery to be allowed to drive your car on Beijing's roads. The lottery system was introduced as a way to reduce congestion. Many Beijing residents decided to buy an electric car simply because the lottery rate – meaning the chance to receive a license plate – can be as low as one in 1907 for fossil fuel vehicles[135]. Local governments also provide supporting incentives such as free parking[136].

(vi) Chance events

"Chance events are occurrences that are outside of control of a firm." "They are important because they create discontinuities in which some gain competitive positions and some lose." (cited from Porter, 1990)

China's pledge to reduce their GHG emissions in accordance with the Paris Agreement can be seen as a chance event that benefits the nation's EV industry. The rising oil price is another chance event that makes electricity more financially attractive for the automotive sector, than fossil fuels.

130 Beijing New Energy Passenger Vehicle Platform, 2018
131 CN Auto News, 2017-12-27
132 Ministry of Transportation, 2018-04-11
133 China Daily, 2016-09-26. See also ICCT, 2018, for a review of China's NEVs mandate policy.
134 China.org.cn, 2011-10-27
135 GB Times, 2018-02-26
136 Xchuxing, 2018-04-29

Conclusion

From the above analysis, we can conclude that China has almost all the factors necessary to build domestic competitiveness for the NEVs industry, which has contributed to China's leadership on the EV market. Other countries have competitive advantages such as the free trade between European countries or the strong supportive role played by the components industry in countries with a longer automotive history – but China's greatest advantage is the coherent and robust national government policy to support NEVs.

NEVs are contributing to China's sustainable development in all three aspects: economic, ecological and social. BEVs have no tailpipe emissions and, despite continued dominance of coal-based energy in China's electricity mix, contribute to reducing environmental pollution and CO_2 emissions. Economically, EVs may help the Chinese manufacturing industry to become more internationally competitive than it has been with internal combustion engine vehicles (ICEs), and with the current subsidies, NEVs may help to reduce the cost of mobility for Chinese citizens. All this puts the Chinese interest and focus on NEVs into perspective, and may help explain why it is likely the focus will be sustained over time, albeit with changing incentives and targets.

However, there are significant differences in terms of benefits for the climate and for the environment, depending on how the NEVs market will develop. A recently published study in Nature Energy shows that electrifying buses and taxis offers the most effective option to reduce emissions and improve air quality, mainly because they are used more and often circulate in the cities where pollution is the worst[137].

137 Chen, 2018

Fact box: China EV100: A sign of Chinese commitment

A sign of China's commitment to NEVs is the establishment in 2014 of the China Committee of Electric Vehicles 100 Members, known as China EV100. It calls itself "the third-party think tank in Chinese electric vehicle area" but is strongly linked to the government. EV100 holds annual meetings at the Diaoyutai State Guesthouse, where President Xi Jinping meets his counterparts, and its members include five ministers from the central government, including Dr. Wan Gang, Minister of Science and Technology, who used to work as an engineer in German Audi Corporation. EV100 is dedicated to advancing the research, development and deployment of New-Energy Vehicles in China, with more than 140 elite members across different industries and fields, from government departments, academic and research organizations, manufacturing and supplier companies related to electric vehicles. EV100 also actively promotes international cooperation: the Sino-British Auto Innovation Forum and Sino-German Auto Industry Summit were parts of the third China EV100 forum which was held in late January 2018.

Frank Yang and Mattias Goldmann

In-depth case study: Electric buses

Reducing pollution from public transport

Buses have many advantages when compared to private cars, including reduced congestion, better fuel efficiency and less emissions per passenger – if used efficiently. However, with the long hours and distance that they travel, buses themselves can contribute to a significant share of pollution in cities if they use conventional fossil fuels. The city of Shenzhen in the Guangdong Province is a case in point. Their 17,000 buses used to run on diesel, and the buses accounted for 0.57% of the total number of vehicles in the city, but 20% of the CO_2 emissions from transport[138]. As we will explore in this chapter, this has been a major reason for the electrification of the bus fleet in Shenzhen, and other Chinese cities follow a similar development path[139].

Electrification of buses in China

China began to promote the adoption of NEVs, including electric buses, in 2009. A pilot project involving 13 cities was initiated to subsidize NEVs purchased for public buses and taxis[140]. In addition, with the Ten Cities Thousand Vehicles project, ten cities were each expected to adopt 1,000 NEVs every year, out of which a large portion was to be buses[141].

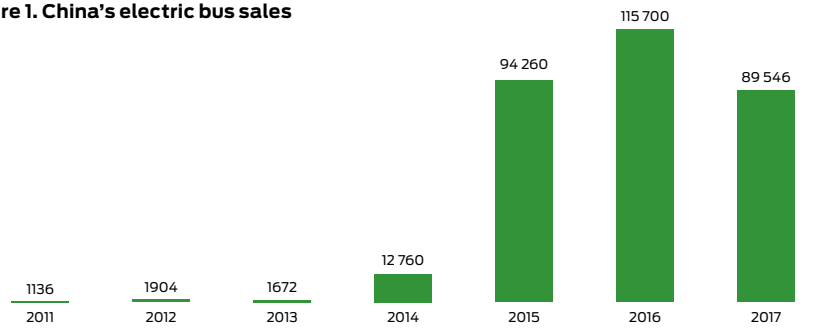
138 Shenzhen Transit Bureau, 2017
139 Statista, 2018d
140 Ministry of Science and Technology of the People's Republic of China, 2009
141 China National Energy Administration, 2012-09-05

Due to high prices and limited production capacity, sales of electric buses stayed at a level below 2,000 per year until 2014, when production and sales of electric buses rose quickly: by 663% in 2014 compared to 2013, and by 638% in 2015 compared to 2014, which is illustrated in figure 1 below. This was largely due to improvements in technology and production capacity, and more importantly, due to more supporting policies. Governmental and public organizations were required in June 2014 to include a growing percentage of NEVs in their new vehicle purchase, and NEVs were exempted from sales tax from September 2014[142]. The tax incentives for NEVs are designed to decrease year by year, with the implication that buyers therefore tend to make their orders early. This likely explains why sales of electric buses decreased in 2017, as can be seen in figure 1 below.

Yutong, China's largest bus producer, sold 20,345 pure electric buses in 2017[143]. BYD, the world's largest EV company, claimed 14.73% of China's electric buses market share the same year[144]. The two companies are also major exporters of electric buses.

By 2025, the total number of electric buses in service in China is forecast to reach 1.2 million, with China as the undisputed leading market for electric buses, according to Bloomberg New Energy Finance[145]. Several cities aim to completely electrify their bus fleet by 2020, including Guangzhou, Nanjing and Foshan[146], and the previously mentioned city of Shenzhen already reached a completely electrified bus fleet by the end of 2017.

Figure 1. China's electric bus sales



Source: EV Obsession, 2018-01-25

142 State Council of China, 2014
143 Yutong, Annual Report 2017
144 BYD, Annual Report 2017
145 As reported by Bloomberg, 2018-02-01
146 Tyncar, 2017-10-27

Mattias Goldmann

In-depth case study: Electric trucks

Electric trucks (e-trucks) are at least as relevant as electric cars when it comes to improving local air quality and reducing the climate impact of transport, since trucks consume more fuel per kilometer and are used more of the time than passenger cars. Until now, the electrification of trucks has not come as far as for passenger vehicles, neither in China or globally, partially since the need for batteries is obviously larger than for a passenger car. This increases the price of the vehicle, but also means that there is a difficult trade-off between the weight of the batteries and the need for payload (revenue-generating capacity). However, a breakthrough seems imminent, with e-trucks being proposed by EV frontrunner Tesla and the start-up company Nikola, as well as manufacturing giants such as Mercedes-Benz, Scania and Volvo – and not least by Chinese manufacturers[147].

The Chinese market for e-trucks

With over 1,000 electric trucks, China is by far the largest market for e-trucks in the world.

In China, as well as elsewhere, a strong driver for e-trucks is to improve air quality[148], but we are also seeing that they can, in some instances, compete on the total cost of ownership, where the higher initial price is offset by large savings on running costs and maintenance compared to regular trucks[149]. Even so, the amount of

147 Navigant Research, 2018
148 Electrek, 2017-03-13
149 The Verge, 2015-02-27

e-trucks is still small compared to electric cars and buses. One important reason for this may be that conventional trucks are very cheap on the Chinese market, and transport companies expect quick return on their investments[150]. Another reason is that at the national level, Chinese NEVs subsidies have focused more on passenger vehicles and buses than on trucks[151].

Cities drive the market

Until now, most e-trucks have been bought by cities as part of their procurement for goods transport, refuse collection and construction machinery, with DHL being a noteworthy private-company customer[152]. Similar to the development in California, ports are now also starting to electrify their transport. An interesting example is the port of Tianjin, which aims to fully automate port operations and is currently testing a domestically-developed self-driving electric truck as part of this endeavor[153].

Shenzhen, famous for being the first city in the world with a 100% electrified bus fleet (see separate chapter on leading cities and sustainable mobility), is also a leader in the introduction of e-trucks. The "Shenzhen Blue" – Shenzhen Sustainable Action Plan for 2018 demands that all new light-duty trucks should be pure electric vehicles from May 1, 2018. By December 31, 2018, 20,000 light diesel vehicles will be eliminated[154]. The city of Shenzhen is electrifying other parts of goods movement as well, including an order for over 500 electric dump trucks[155]. The CO_2 emissions of a traditional dump truck are estimated to be equivalent to 70 passenger cars, which shows the large potentials for climate gains in the move towards electrification[156].

The national authorities in China have issued a list of e-trucks eligible for a purchasing allowance, consisting of 15 electric models from six manufacturers[157]. By far the largest producer of e-trucks is BYD, which produced its first light

150 Carnews China, 2014-08-11
151 Ce.cn, 2017-08-15 & CN Auto News, 2017-08-15
152 Itdcw.com, 2017-11-25
153 See Youtube video at https://www.youtube.com/watch?v=gpBbES6cRVc
154 Shenzhen Habitat and Environment Committee, 2018-04-21
155 Electrive, 2018-05-15
156 Electrive, 2018-05-15
157 Sohu, 2017-12-27

e-truck in 2014. The company now has a full range of e-trucks, ranging from 3.5 tons to 44 tons, with a claimed lower TCO (total cost of ownership) than comparable diesel trucks[158].

BYD has also started production of e-trucks in California[159], a market over 100 times larger than California's bus market. The initial focus is on the delivery market, goods movement at ports and garbage collection[160]. BYD has also opened a manufacturing facility in Europe (Hungary)[161], with another factory in Canada announced for 2019[162].

As shown in this brief chapter, Chinese cities are helpful in ensuring that there is a market for e-trucks, at least in some sectors. It remains to be seen how the more general market for electric trucks will develop, though at least on the production side, China is clearly taking up the challenge with its European and American competitors.

158 Presentation from the Zero conference in 2017, available at: https://zerokonferansen.no/wp-content/uploads/2017/11/3A-4-Javier-Contijoch.compressed.pdf
159 BYD Motors, 2018
160 Truck News 2017-10-26
161 BYD Europe, 2018
162 Electrek, 2017-11-15

Mattias Goldmann

In-depth case study: Ride-sharing and car-sharing

Can sharing reduce China's congestion?

As has often been reported, China's infrastructure is struggling to keep up with the rise in passenger cars, resulting in congestion, gridlock and losses in productivity. Furthermore, local air quality has suffered from the large number of vehicles, including around five million passenger cars in Beijing alone. This has led several Chinese cities to reduce the number of cars, through license-plate control policies and other transport-demand management strategies[163]. Car-sharing and ride-sharing may be important and relevant parts of this work. However, it is important to realize that increased availability and accessibility of passenger cars might lead people to travel more by car[164].

Fast growth for ride-sharing

Ride-sharing has grown much faster than car-sharing, with the leading company Didi, founded as the result of a merger in 2016 between two rival ride-sharing companies[165], alone having more than 450 million users across more than 400 cities in China[166]. Around 25 million Chinese use Didi on an average day, though the number has risen and shrunk depending on the current level of subsidies and marketing campaigns. It is claimed that 80% of all taxi drivers in China now use Didi to find passengers, and that it can be difficult to get a cab during rush hour

163 China Daily USA, 2014-03-25
164 Bert et al, 2016
165 Reuters, 2015-02-14
166 People's Daily, 2017-10-26

without the Didi app[167]. With 25 million rides per day, it is estimated to surpass all other ride-sharing companies around the world[168]. Part of the reason for this is that it took over Uber's business in China, after a long and expensive battle for market share. Didi partnered with Volkswagen to build the first purpose-built vehicle fleet and this partnership will also allow the company to enter the autonomous driving arena[169]. Didi is now valued at $50 billion, making it the world's second-most valuable tech startup, after Uber[170].

Ride-sharing has been accelerating the introduction of electromobility in China, with Didi claiming to operate the world's largest fleet of electric cars. Didi has 260,000 of the two million electric vehicles currently on the road in China, and a target of one million electric vehicles by 2020[171]. To achieve this, Didi is building its own charging network in China in partnership with the United Nations and GEIDCO, the Global Energy Interconnection Development and Cooperation Organization[172].

While Didi is by far the largest in ride-sharing, there are competitors including Cao Cao, backed by Volvo-owned automotive giant Geely. Cao Cao, which has more of a business-to-consumer focus than Didi, has raised more than one billion yuan and has around ten million users in 17 cities, while the bicycle-sharing platform Mobike is also launching a car ride-sharing platform. This is part of the explanation for Didi's expansion into other countries, including Japan and Brazil[173].

Car-sharing: Big potential, slow start

The global car-sharing market is growing fast. It was valued at $1.2 billion in 2015 and will hit $16.5 billion by 2024, according to Global Market Insights, which also sees China as one of the markets that will grow particularly fast[174].

Currently, car-sharing in China accounts for less than 0.5% of all car usage in China, far lower than in South-East Asian and European countries[175]. In its report,

167 Bloomberg, 2016-10-06
168 Statista, 2017-07-17
169 Fortune, 2018-04-30
170 The Verge, 2017-05-02
171 Techcrunch, 2017-12-21
172 Techcrunch, 2017-11-02
173 Nasdaq, 2018-02-08
174 Reuters, 2018-02-07
175 China Daily, 2016-04-18

Boston Consulting Group sees a growing potential for car-sharing in China, particularly among the younger population in large cities, where the appeal of private car ownership is weakening[176]. In a separate study, Nielsen found that 67.8% of the Chinese respondents who do not own cars "feel there's no need for a private car", 32.4% of private cars owners said they wouldn't buy another car and 9.7% considered selling their cars[177]. Car manufacturers BMW, Daimler and Toyota have all launched car-sharing projects in China, each of them with a fleet of several hundred vehicles, and an electric car-sharing service is being set up with 12 automakers, including Ford, Renault, Nissan and Mitsubishi[178]. In addition, Chinese companies such as EVCARD in Shanghai[179] and GoFun in Beijing[180] have specialized in EV car-sharing. At the same time, the ride-sharing giant Didi has also entered the car-pooling market, as a way to reduce the number of drivers they need[181].

The way ahead: Challenges and opportunities

While car ownership is seen as a status symbol by most Chinese, the rapidly changing attitudes of the young inhabitants of large cities show that the market potential for car-sharing and ride-sharing may grow very quickly. This change would come quicker with supportive policies from cities, including regulations for on-street parking for shared vehicles and exemption from the license-plate based restrictions specifying days on which cars are allowed to be used in certain cities[182]. Then, car-sharing and ride-sharing could become an important part in China's ambitions to ensure that transport is more sustainable. For car-sharing to become synonymous with EVs, additional hurdles will probably need to be overcome, including the relative lack of governmental support compared to other sectors of sustainable mobility, the need for appropriate charging infrastructure, and the longer payback time for EVs compared to conventional vehicles.

176 Boston Consulting Group, 2018
177 China Daily, 2016-04-18
178 China Daily, 2016-04-18
179 EVCARD, 2018
180 GoFun, 2017
181 Thomson Reuters, 2018-01-25
182 Urban Gateway, n.d.

Frank Yang and Mattias Goldmann

In-depth case study: Shared bicycles

Bicycle-sharing has become an important part of China's efforts to improve local air quality and reduce CO_2 emissions. There are currently shared bicycles in more than 200 Chinese cities, with around 25 million bicycles, 400 million registered bicycle-sharing users and up to 70 million daily riders, according to Liu Xiaoming, vice minister of the Ministry of Transportation[183].

In 2017, shared bicycles reduced emissions by 4.22 million tons of CO_2 in China, while emissions of particulate matter PM2.5 were reduced by 3.22 million tons, according to the report *The economic and social impacts of shared bicycles 2017*[184] which compares the current situation with a theoretical business-as-usual scenario, in which journeys conducted by bicycle would otherwise be undertaken by public transport and passenger cars. Furthermore, 1.41 million tons of gasoline was saved, corresponding to a cost of 12.4 billion yuan, and 400 thousand hours of congestion was avoided, which the China Academy of Information and Communications Technology (CAICT) has translated into a labor cost saving of 16.1 billion yuan. The industry's revenue is estimated at above 220 billion yuan, with almost 400,000 jobs, according to CAICT[185].

In addition, several Chinese bicycle-sharing companies, including Mobike and Ofo, launched overseas in 2017 and 2018, including in Berlin, Tokyo and Washington D.C. In some of these locations, the Chinese companies are the first to bring such a service to the inhabitants, though in most, they compete with existing services[186].

183 People's Daily, 2018-02-08
184 China Academy of Information and Communications Technology, 2018
185 China Academy of Information and Communications Technology, 2018
186 Where not otherwise indicated, the information in this chapter was retrieved from the annual Transportation Research Board (TRB) conference, as described at http://2030-sekretariatet.se/lanecyklar-kina/ (in Swedish)

The history of shared bicycles in China

The evolution of shared bicycles in China can be divided into three stages, according *to China's Shared Bicycle Market Research Report*[187]. While the three stages overlap and co-exist, this can be seen as a rough timeline:

1. **Shared bicycles with fixed parking, provided from public authorities**, which started in 2007, when the concept of bicycle-sharing was imported to China. Hangzhou city started providing shared bicycles for free in 2008[188], and was listed as one of the eight cities with best public bicycle service by the BBC travel channel[189].
2. **Shared bicycles with fixed parking, provided from private initiatives**, which started in 2010, when Yong'an Bike began to provide a management service for public shared bicycles[190].
3. **Shared bicycles with floating parking, provided from private initiatives**. Floating systems started in 2014, when the bicycle-sharing company Ofo was founded to provide bicycle-sharing services on campuses, with the first 2,000 bikes at Beijing university in September, 2015. Ofo was the first company to offer bicycles that can be picked up and returned anywhere within the campus, city or region in which the company operates.

The bicycle-sharing industry did not get much public attention until the second half of 2016, when venture capital poured in, and Ofo and Mobike were valued at more than ten billion yuan each. In 2017, the industry grew rapidly, with more than 20 million bicycles from several different brands in Chinese cities, almost ten times as many as in 2016, according to *China's Shared Bicycle Market Development Report*[191].

187 Bigdata Research, 2017
188 Urbanchina.org, 2013-10-24
189 Bigdata Research, 2017
190 Sixth Tone, 2017-12-30
191 Mobike, 2018

Driving forces for bicycle-sharing

Demand

In Chinese cities, the nearest bus or metro station can often be hundreds or thousands of meters away, and the so-called last-mileage problem can be solved by bicycles. Also, using the bicycle as a means of transportation is embedded in the everyday culture and has been a natural part of daily life[192]. Furthermore, congestion in large cities often makes riding a bicycle a faster and more convenient choice than going by car or bus. At universities with large campuses, a slightly different logic applies: the private car may not be an option, but the flexibility of the bicycle is highly valued. An added factor is that many private bicycles are stolen, which makes shared bicycles an attractive, low-risk alternative.

Technology

Our analysis is that the success for shared bicycle systems depends on two key features:

- *They are dockless* and thus can be picked up and left anywhere where parking a bicycle is legal. This is ensured by mobile solutions, where the bicycle has a code that is scanned and linked to an account for registration, location and payment.
- *They are almost maintenance-free.* Technologies such as a chainless shaft transmission, non-puncture airless tires, a lightweight aluminum anti-rust frame, and enhanced and durable disk-brakes are adopted for most of the bicycle-sharing systems[193], to minimize the need for maintenance, which is costly for the operator and inconvenient for the user.

Venture capital

Even though the individual bicycles used in sharing systems are typically low-cost, launching a system typically means putting thousands of bicycles on the roads, establishing a charging system and heavily marketing the product before any income is generated. For this reason, venture capital has been central to

192 Citylab, 2017-04-06
193 See e.g. Business Insider, 2017-12-05

establishing bicycle-sharing systems, with more than 20 billion yuan invested in less than two years, according to The Deathlist of Shared Bikes[194]. Mobike and Ofo have been the largest destination for investment, but more than 40 companies have been established, with a real risk of market overcrowding.

Challenges

Parking

The availability of dockless bicycles is a double-edged sword. On the one hand, it brings convenience to users, who do not have to go to dedicated bicycle stands to find the bicycles. Instead, they can pick up and leave them anywhere it is legal to park them. On the other hand, as often reported by media, it has led to a situation where "regulators are frowning upon the free-to-park two wheels as they clog city sidewalks, give rise to traffic accidents and lead to a flood of consumer complaints."[195] Part of the reason is that bicycle-sharing companies compete to have the greatest number of bicycles on the streets, thereby limiting the cost for moving the bicycles from one place to another.

Among the measures that are being taken to improve the situation, the authorities in Nanjing and Shanghai demand that every bicycle is to be registered with license plates, which will make it easier to track them.

Usage

The shared bicycles are mainly used to get to and from work as well as to ride home for lunch. The average user in China is around 30 years old and earns slightly less than the average income. Almost half of the users have access to a car, while fewer have their own bicycle. An average trip is just under half an hour, which in many of the Chinese cities with shared bicycles is the limit for free rides, all of this according to research by Mengwei Chen at Zhejiang University[196].

Other research concludes that the poor air quality is a major hindrance for use of the bicycles. When the air quality is particularly bad, people prefer to take the

194 Wang, 2017
195 Forbes, 2018-01-26
196 Research presented at the in-depth session on shared bicycles at the 2017 TRB conference in Washington DC, described by 2030-sekretariatet, 2017

car or bus, which becomes a self-reinforcing negative spiral. This is especially true for women, the elderly and for those with higher incomes. Thus, for shared bicycles to become more widely used, and for the potential air quality benefits to fully materialize, air quality must be improved. Furthermore, the effects of climate change itself may make cycling less attractive from a longer-term perspective. The use of the bicycle-sharing systems declines when temperatures exceed 30 degrees centigrade, when it is windy or raining[197].

Profitability

"No one makes money on shared bicycles for the first three years", claim the experts behind Bikesharingmap.com[198]. That certainly seems true for China, where the hourly rate for a bicycle is around one yuan – often lower due to the intense competition for market share. With an average usage of three hours per day per bicycle, it will take more than two years to cover the cost of the bicycle, much more with all costs factored in. In addition to the cost of the bicycle itself, there are added costs for repairs, shipping, marketing, labor and replacement after theft and vandalism, which is still a major concern, even though some reports indicate that the negative attitude towards shared bicycles has been exaggerated[199].

The future of bicycle-sharing in China

Our analysis is that the future of the bicycle-sharing systems can be seen as being dependent on several key factors:

a) **The appetite to invest** of venture capital: further economic injections from the owners, to a large part consisting of venture capital companies, will likely be needed for the companies to survive, before they become profitable.

b) **Market consolidation**: With more than 70 bicycle-sharing companies in China, mergers and acquisitions are to be expected, and would pro-

197 Based on the annual TRB conference, as described by 2030-sekretariatet, 2017
198 Based on the annual TRB conference, as described by 2030-sekretariatet, 2017
199 New York Times, 2017-09-02

bably be in the interest of both the business and the consumer[200].

c) **Raising rates and reducing the number of bicycles:** This might be inevitable if the operators are going to survive, but may only happen if the number of companies in the market is reduced through mergers and acquisitions[201].

d) **Good consumer behavior** may need to be incentivized by the charging model, as a part of increasing acceptance from residents for bicycle-sharing.

e) **Local-government acceptance**. Beijing, Shanghai, Guangzhou, Shenzhen and several other cities have imposed restrictions on introducing new shared bicycles. For the business to thrive, the bicycle-sharing companies need to find a way to co-exist and integrate their offer with the cities' work for sustainable transportation.

f) **National government acceptance**. Until now, there has been little in the way of national incentives or restrictions for bicycle-sharing. If it becomes a strategic part of China's commitment towards improved air quality and reduced climate impact, the business will benefit, while if national restrictions are imposed, that will be a significant obstacle to overcome.

200 South China Morning Post, 2017-12-05
201 Fortune, 2017-03-21

Frank Yang

In-depth case study: Passenger rail transport

More people travel by train

March 12, 2018 was the last day of the Spring Festival Travel Season, or Chunyun in Chinese, when people return from work or study to celebrate Chinese New Year with their family. The total number of passenger journeys by train in China during the preceding 40 days of Chunyun hit 382 million[202], which is larger than the population of the U.S. Travel by train accounted for 12.86% of the total of 2.97 billion passenger-journeys during Chunyun, whereas airplane travel accounted for 2.2%, and road transportation accounted for 83.5% of the journeys. The development of travel by train during Chunyun from 2002-2018 is shown in figure 1 below. Both the number of passenger journeys by train and their percentage of the total journeys have been increasing steadily in recent decades. Back in 2002, the number of passenger journeys by train was 130 million and their percentage of the total journeys was 7.47%, according to statistics from Ministry of Transportation[203].

As shown in figure 2 below, the total number of passenger trips during Chunyun increased at about the same rate as the percentage of passenger journeys by train until 2014. After 2014, the total number of passenger trips started to decline, at the same time as passenger journeys by train kept increasing.

The growth in journeys by train can be partially explained by the expanding rail transport network and faster trains, especially the development of high-speed rail. Another reason is the low average price for train tickets, 0.42 yuan (around

202 According to statistics from Ministry of Transportation, as reported in People's Daily, 2018-03-15
203 As reported in People's Daily, 2018-03-15

Figure 1. Travel by train during Chunyun, 2002-2018 (in million trips)

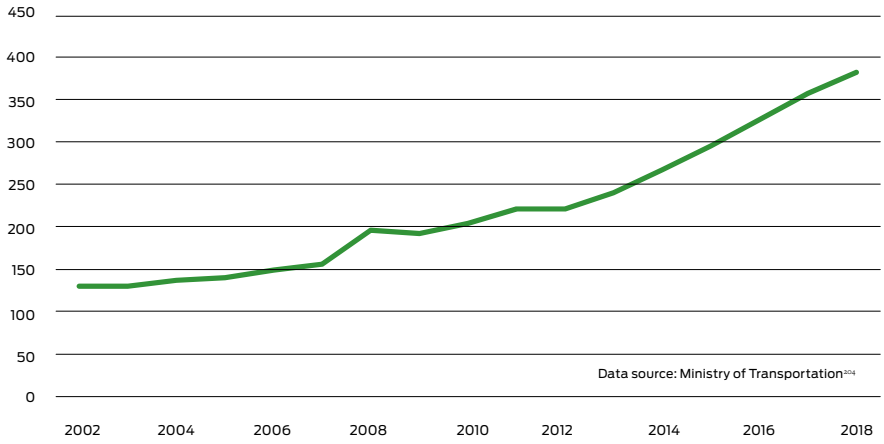
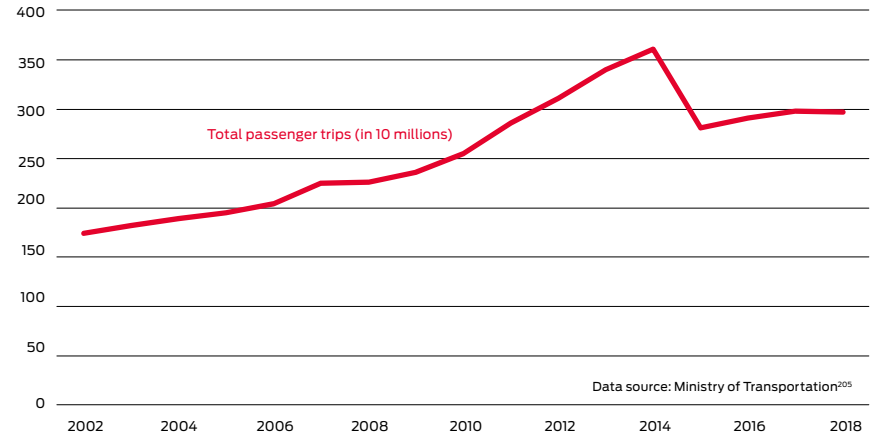


Figure 2. Total number of passenger trips during Chunyun, 2002-2018 (in ten million trips)



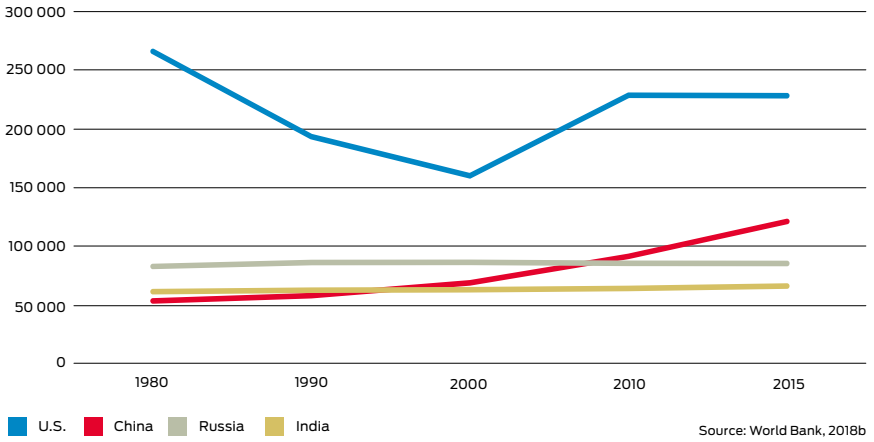
0.5 Swedish kronor) per kilometer[206]. The price for train tickets has increased at a slower rate than the average Chinese income, making the trains more affordable over time. Other reasons include the restrictions on private car usage in China, described in other chapters.

204 As reported in People's Daily, 2018-03-15
205 As reported in People's Daily, 2018-03-15
206 As reported in Beijing News New Media, 2017-02-17

An expanding transport network

China's rail network was the world's fourth largest in the 1980s, in terms of railway length. Between then and 2015, China's railway length increased by 127% to 121,000 kilometers, while India's increased by 8%, Russia's increased by 3% and the U.S.'s decreased by 14%, according to statistics from the World Bank[207]. This means that China's rail network is now the world's second largest, after the U.S.'s – and China's railway is still expanding at a considerable rate[208]. The size of China's rail network compared to the U.S., Russia and India is shown in figure 3 below.

Figure 3. Rail transport network size in China compared to the U.S., Russia and India, 1980-2015 (in kilometers)



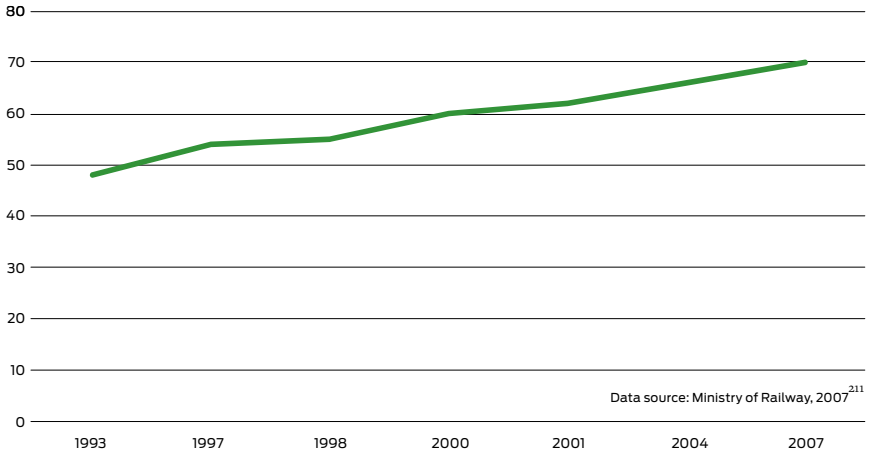
Source: World Bank, 2018b

Speeding up trains

During 1997-2007, six rounds of speed-up campaigns were conducted to modernize the railway system and to regain market share taken by aviation and highways. As a result, the average speed of passenger trains increased to 70 km/h from 48 km/h[209], which is shown in figure 4 below. Also, a speed of 250 km/h was achieved on 846 kilometers of existing railway lines[210].

207 World Bank, 2018b
208 Railway technology, 2014-02-19
209 Central Government Portal, 2007-05-03
210 Data from press conference held by Ministry of Railway, 2007-04-12

Figure 4. Average speed of passenger trains, 1993-2007 (in km/h)



High-speed rail

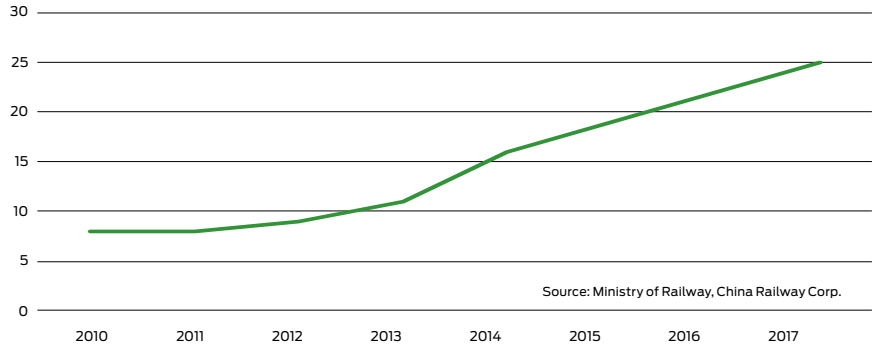
China decided to construct 12,000 kilometers of passenger-dedicated railway for trains running at a speed of 200 km/h or above in January 2004[212], which can be seen as the start of China's high-speed rail initiative. Contracts for train purchase and technology transfer were signed the same year between China and companies from France, Canada and Japan. In 2008 China began to independently develop trains with a speed of 350 km/h[213].

Investment in high-speed rail benefited from the four trillion-yuan stimulus plan, announced in late 2008, with the aim to counteract the international economic crisis. By the end of 2010, China had constructed 8,358 kilometers of high-speed rail, which was already the longest in the world, accounting for about one-third of the world's high-speed rail track in commercial service[214].

A collision between two high-speed trains on July 23, 2011 caused 40 deaths and led to the temporary suspension of new projects[215]. The running speed of trains was cut down and the number of passengers fell, which is also reflected in

211 Reported by People's Daily, 2018-03-15
212 Ministry of Railway, 2004
213 Ministry of Railway, 2008
214 Data from Ministry of Railway, as reported by People's Daily, 2011-01-04
215 Hexun, 2011-07-29

Figure 5. China's high-speed rail length, 2010-2017 (in thousand kilometers)



the Chunyun train trip decline in 2012, visible in the first figure of this chapter. Construction resumed in the second half of 2012 and started booming in 2014[216].

By the end of 2017, China's high-speed rail network had grown to 25,000 kilometers, connecting 29 of China's 33 provinces. The development of China's high-speed rail network is shown in figure 5 above. As of September 2017, a cumulative number of seven billion trips were delivered by high-speed railway, according to China Railway Corp[217]. The high-speed trains contribute directly to emissions reduction when replacing other modes of transport, particularly aviation and passenger cars[218]. This is due to high-speed trains being electric, while most other modes of transport mainly use combustion engines. Furthermore, most conventional trains are still diesel-powered[219].

The 13th five-year plan for railways

The 13th five-year plan for the development of railways[220] was published in November 2017. Some of the targets for the year 2020 listed in the document include:

- Total length of railway: 150,000 km
- Length of high-speed railway: 30,000 km

216 Information Network, 2012-05-25
217 As reported by China News Network, 2017-10-23
218 Horvath and Chester, 2012
219 Horvath and Chester, 2012
220 Ministry of Transportation, National Development and Reform Commission, National Railway Administration and China Railway Corporation, 2017

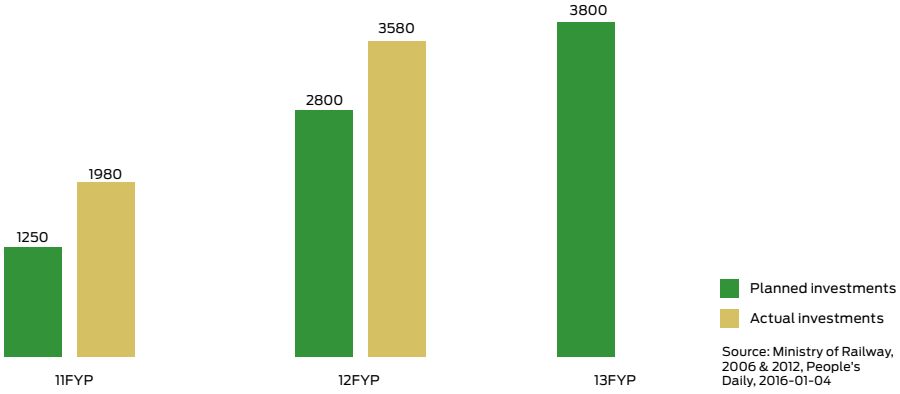
- Electrification rate of railway: 70%
- Big city coverage rate by high-speed railway: 80%

The ambition will be supported by an investment of 3.8 trillion yuan[221]. The actual investments will normally be much larger. Actual and planned investments in railways, according to the 11th, 12th and 13th FYP:s, are shown in figure 6 below.

International cooperation

China has been pushing the exportation of its high-speed railway solutions. It is also seen as part of its "One Belt, One Road" initiative[222] to increase trade and infrastructure links with countries from Asia, Europe and West Africa, with infrastructure projects including roads, railways, telecommunications, energy pipelines and ports. Two Chinese companies took part in the Ankara–Istanbul high-speed railway, which was completed in July 2014[223]. Cooperation contracts with Russia and other countries were also signed[224]. It was reported that a delegation from China's Association for Promoting International Economic and Technical Cooperation had visited Oslo in late January 2018 to discuss the poten-

Figure 6. China's investment in railways in the 11th, 12th and 13th FYP (in billion yuan)



221 13th five-year plan for railway (Draft for Comment), available at People's Daily, 2016-01-04. The estimated amount of investments is only available in the draft.
222 Marco Polo Study, 2017-10-02
223 Sinosphere, 2014-07-28
224 Reuters, 2017-06-20

tial for a high-speed rail link between Oslo and Stockholm[225].

High-speed rail, however, is not suitable for every country. China has travel demand from a big population, a government that can issue debt to invest in railways, and public land that can be easily acquired. These factors are not available in every country. That partially explains why many of China's overseas rail projects have stalled. However, as passenger travel by high-speed train increases in China, more people should become aware of the environmental and economic benefits, particularly the gains in efficiency compared to a clogged road network and the recurring delays associated with aviation: among the world's 61 largest airports, the seven worst performers of on-time departures were all Chinese airports, according to FlightStats[226].

225 Silk Road Briefing, 2018-01-31
226 South China Morning Post, 2015-03-20

Mattias Goldmann

In-depth case study: Autonomous vehicles

China sees autonomous vehicles as an important part of the Made in China 2025 roadmap, launched by the State Council in 2015, with the goal of transforming the country into an innovation hub in a variety of sectors, including the automotive industry[227]. Whilst other countries may have a technological advantage over China when it comes to conventional vehicles, China may be able to compete on more equal terms in this section of the market (see below).

A key reason for China's ambition in this area is to reduce the traffic-related death toll, responsible for the death of more than 250,000 Chinese each year. Early Chinese regulations for autonomous vehicles put strong emphasis on how the technology can help to reduce the number of fatalities, often caused by human error[228]. Autonomous vehicles may also be part of reducing Chinese traffic congestion, since they can be operated much more efficiently, reducing the need for parking space and decreasing the needed space between vehicles driven. Furthermore, there are clear environmental and climate benefits when vehicles are driven more efficiently than with humans behind the wheel[229]. However, other studies indicate that autonomous vehicles could lead to an increase in passenger car travel, counteracting the benefits of reduced congestion[230]. The final effects are, to a large degree, decided by which policy measures are put in place.

227 English.gov.cn, 2018-04-05
228 HerbertSmithFreehills, 2018-02-13
229 Business Sweden, 2016
230 Affinitiv, 2017-11-02

Driverless cities

The Chinese city Wuhu aims to become the world's first totally driverless city by 2025, working with the Chinese search engine giant Baidu[231], which has also been given the permission to test its autonomous vehicles on 33 roads in Beijing's less-populated suburbs[232]. Chinese-owned, Swedish-based car manufacturer Volvo has also been testing autonomous vehicles in Beijing. Ride-sharing giant Didi is also moving into autonomous driving, opening a research lab in Silicon Valley in 2016[233], and has established a research institute focusing on how artificial intelligence (AI) technologies can optimize city transport, working with Jinan, Wuhan and other cities[234]. China also plans a solar-powered 150 km expressway, charging vehicles as they go, and designed to support driverless vehicles between cities. The first part of the highway is expected to open in 2021[235].

National targets

In July 2017, China issued a roadmap with guidelines on developing AI, setting a goal of becoming a global innovation center in this field by 2030[236].

The guidelines specify a number of focus tasks, including the development of "Unmanned and autonomously controlled systems including automobiles, ships, automatic driving in traffic, etc." The roadmap also aims to "strengthen the integration and coordination of vehicle load sensing and automatic driving" and to, among other things, "Research and develop information and integrated data platforms for transportation under complex multi-dimensional conditions, and establish intelligentized transportation command, control, and integrated operations."[237]

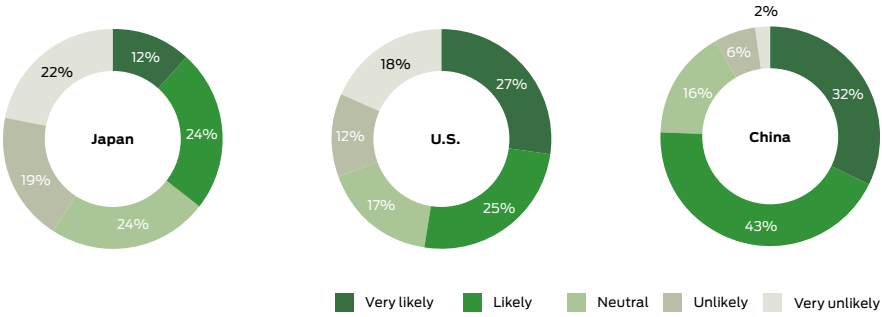
More concrete than the plan, China's Ministry of Industry and Information Technology aims for extensive autonomous highway driving by 2020 and fully autonomous urban driving by 2025. This should reduce traffic accidents by more

231 CKGSB Knowledge, 2016-11-21
232 Reuters, 2018-03-23
233 The Verge, 2016-10-06
234 The Beijinger, 2017-08-30
235 The Daily Mail, 2018-03-01
236 State Council of China, 2017-07-20
237 China Copyright and Media, 2017-07-20

than 30%, lower energy consumption by 10%, and reduce emissions by more than 20%. The first steps, after the current trials, will most likely be dedicated bus and fixed route taxi lanes in major cities, since such pre-defined and measurable trips are the easiest to implement[238].

The Chinese ambitions are "Not a Moonshot, but a Legacy of Central Planning", according to the New America Cybersecurity Initiative[239], while the research institution IHS claims that China has the potential to become a world leader in self-driving cars, predicting that 5.7 million cars on Chinese roads will have some degree of autonomy by 2035[240]. Boston Consulting Group believes that China will by then be the largest market for autonomous features, accounting for at least a quarter of global demand. This would be well received: in the 2015 World Economic Forum survey, 75% of the Chinese surveyed said they would want to ride in a self-driving car, compared to around half of the Americans[241]. This is shown in figure 1 below.

Figure 1. Consumer attitudes towards self-driving cars expressed as % of respondents likely/unlikely to try a self-driving car



Source: World Economic Forum, 2015 and Statista, 2015

Obstacles to overcome

The Chinese regulatory processes related to autonomous vehicles are national rather than regional or city-based, which, in combination with the centralized processes, enables China to develop the policy framework for autonomous

238 Forbes, 2016-02-02
239 New America, 2017-08-01
240 CKGSB Knowledge, 2016-11-21
241 Fortune, 2016-04-23

vehicles faster than many other countries. Even so, a coherent national policy framework for autonomous vehicles is yet to be designed, with a need for greater clarity on who regulates what. Another issue of concern for the Chinese development is the restrictions on the development of physical maps, since very detailed maps are needed for fully automated driving – therefore, the roadmap towards self-driving cars may be hindered by the lack of road maps. Furthermore, current Chinese rules stipulate that drivers must be in the vehicle with their hands on the steering wheel, which obviously complicates the introduction of autonomous vehicles[242]. While this is similar to the need for modernizing the legislation in many other countries, it still shows that not even China is fully ready for the introduction of autonomous vehicles.

242 West, 2016

Frank Yang, Jakob Lagercrantz and Mattias Goldmann

In-depth case study: Biofuels

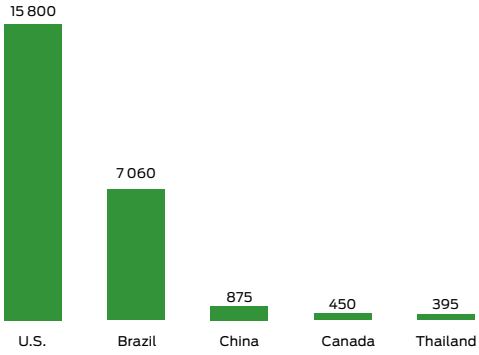
China's food security and biofuel industry

China has 18.5% of the total world population, but only 8.8% of the world's arable land[243]. Arable land per capita was 0.09 acres in 2015, just under half of the world average of 0.19[244]. This means that food security must be given a high priority, not least after the population increases over the past decades. A national grain reserve system was introduced in 1990 with a reserve of 200 million metric tons[245]. Additionally, starting in 2004, the nation set minimum purchasing prices of grains to secure a certain level of plantation[246], which helped the country to better withstand the effects of the 2007-08 global food price hike[247].

The reserved grains are no longer edible after being stored for more than three years, but can be used to produce bioethanol or feed livestock and poultry, which are the only two legal usages of aged grains. China started its first bioethanol project in 2001[248]. Starting in 2003, gasoline with 10% ethanol (E10) replaced traditional gasoline in nine provinces[249]. The industry developed quickly until 2007, when the government stopped the construction of new ethanol factories due to an international food price hike[250]. After that, the industry has again developed, albeit at a slower pace, and China has become the world's third-largest ethanol producer. Its production, however, is far below that of the U.S. and Brazil[251], which can be seen in figure 1 below.

243 Worldometers, 2018
244 World Bank, 2018c
245 State Council of China, 2013
246 State Council of China, 2006
247 FAO, n.d
248 Bioenergy International, 2016-09-20
249 Sohu, 2006-05-18
250 National Development and Reform Commission, 2007
251 Statista, 2018e

Figure 1. Bioethanol production in the U.S., Brazil, China, Canada and Thailand in 2017 (in million gallons)



Source: Statista, 2018e

Ethanol production is forecast to grow with a strong emphasis on domestic production, given the joint ministerial development plan Expansion of Ethanol Production and Promotion for Transportation. A key component is to introduce a nationwide E10 blend: all gasoline is to have 10% ethanol by 2020. Today, the ethanol mix in gasoline is estimated at 2.3% as a national average[252]. The plan also outlines a move towards cellulosic ethanol. Currently, China favors ethanol production from cassava, sweet sorghum and other non-food sources. These feedstocks are considered advanced. Biofuels from crops are not encouraged, since Chinese national policies are based on the belief that the land is needed to feed the growing population[253].

In order to meet the E10 target, a coal-to-ethanol plant was launched in January 2017. The production is starting at 100,000 metric tons, but can expand to 1,000,000 metric tons[254]. This would be 25% of the current ethanol for fuel consumption in China, but would also mean that in the Chinese context, ethanol must to a large degree be seen as a fossil fuel that generates substantial CO_2 emissions.

Biodiesel production remains fairly low in China, amounting to less than half

252 USDA Foreign Agricultural Service, 2017
253 USDA Foreign Agricultural Service, 2017
254 USDA Foreign Agricultural Service, 2017

the volume of ethanol, and with a low usage of the existing production capacity[255]. Factories were generally built to recycle used cooking oil (UCO), also known as gutter oil. The yearly production of UCO is estimated at more than 13 million metric tons, even though the latest figures that we know of are from 2010[256].

The biodiesel is used mainly for industrial and agricultural purposes, while in transport, biodiesel constitutes only 0.1% of all diesel. There are regional differences, and in theory the blending rate can be as high as 30%[257].

According to the China National Grain and Oils Information Center[258], 35.05 million metric tons of cooking oil was consumed in 2017-18. Biodiesel production capacity began to build from 2004 and reached three million metric tons in 2008, according to USDA[259]. However, real production was only 10% of the capacity[260], since the international food price hike led to a demand for gutter oil to be reused as cooking oil. The price of UCO surged from 2,000 yuan per metric ton in 2006 to 5,400 yuan per metric ton in 2007, with virgin cooking oil at even higher price levels. At these prices, producing biodiesel became financially unattractive. Another hindrance is the lack of a national mandate for biodiesel, which means that the market is, to a large part, dependent on the ability to sell biodiesel to gas-station owners, who often see limited reasons to include biodiesel in their offerings[261]. China's biodiesel production in 2016 was 0.3 billion liters, which is equivalent to 10% of Germany's production or 5.5% that of the U.S., according to statistics from Statista[262].

Biogas is common in China, though not for vehicle usage. This is partially due to the fact that biogas production in China typically takes place in small and inexpensive digesters, often at a household level in rural communities, whereas biogas for vehicle usage requires expensive and technically complex upgraded facilities[263]. To our knowledge, no pilot project has been conducted for biogas for vehicle usage. However, the potential is there, with more than one million com-

255 USDA Foreign Agricultural Service, 2017
256 Zhou, 2017
257 USDA Foreign Agricultural Service, 2017
258 China National Grain and Oils Information Center, 2018
259 USDA Foreign Agricultural Service, 2009
260 USDA Foreign Agricultural Service, 2009
261 China Venture, 2008
262 Statista, 2018f
263 Zuzhang, 2013

pressed natural gas (CNG) vehicles on the road, according to the Natural Gas Vehicle Knowledge Base[264]. Since the natural gas used is technically composed of the same methane as in biogas, there is potential for a switch from CNG to compressed biogas (CBG).

Biofuels in the 13th five-year plan

Biofuels form a part of renewable energy, which is one of the strategic emerging industries in the Chinese government's five-year plan. However, the 2020 targets for biofuel (shown in figure 2 below) are less ambitious and less well defined than that of other strategic emerging industries such as NEVs. The related paragraphs from the 13th five-year plan for the development of renewable energy are quoted as follows[265]:

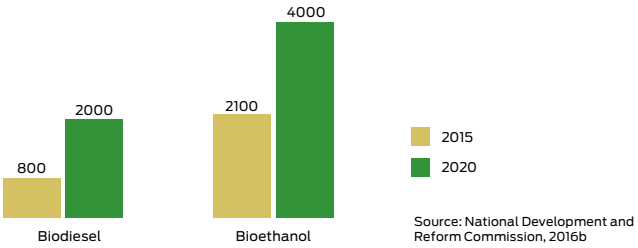
"Promote industrialization of liquid biofuel. *Steadily expand fuel ethanol production and consumption. Based on domestic technological capacity, actively introduce, digest, and absorb advanced foreign experience, and vigorously develop cellulosic ethanol. Combined with the consumption of tainted and heavy metal polluted grain, control the development of the total volume of fuel ethanol from grain. According to resource conditions, appropriately develop fuel ethanol projects using cassava, sweet sorghum, and other crops. Upgrade biodiesel projects, improve product quality, and meet fuel quality requirements for transport fuels. Accelerate the technological innovation for poly-generation of liquid bio-fuels and other products from woody biomass, micro-algae and other non-grain raw materials. Promote applied demonstration for the industrialization of the refinery of high-grade fuel oils from biomass, and bio-based aviation fuel. By 2020, the annual consumption of liquid biofuels will exceed 600 million tons."*[266]

"Accelerate biogas demonstration and industrialization. *Selecting large counties rich in organic waste resources from crop production and animal husbandry, with the county as a unit, establish an industrial system, carry out construction of biogas demonstration counties, and promote the progress of bio-natural gas technology and modernization of engineering and construction. Establish raw material collection safe-*

264 National Gas Vehicle Knowledge Base, 2012-06-15
265 National Development and Reform Commission, 2016b
266 National Development and Reform Commission, 2016b, pp. 21-22

guards and systems for the use of biogas slurry as organic fertilizer. Establish a transmission and distribution system for bio-natural gas, and create diversified consumption by connecting it to conventional natural gas pipeline networks, use as vehicle fuel, for power generation, and as industrial boiler fuel, etc. By 2020, annual production of bio-natural gas will be 8 billion cubic meters, and 160 bio-natural gas demonstration counties will have been constructed."[267]

Figure 2. China's liquid biofuel targets for 2015 and 2020 (in thousand metric tons)



A seemingly brighter future for bioethanol

In September 2017 China announced that it would roll out the use of E10 nationally by 2020. Presently the use of E10 is limited within 11 of the nation's 31 provinces (not including Hong Kong, Macau and Taiwan)[268].

This is an aggressive adjustment to the 2020 target in the 13th FYP. China consumed 119.8 million metric tons of gasoline in 2016, according to National Statistics Bureau of China[269]. If all gasoline sold in 2020 were to be blended with 10% bioethanol, at least ten million metric tons of bioethanol would be needed, which is 2.5 times that of the four million-ton target from the 13th FYP.

The country's deteriorating reserve grain will then no longer be sufficient for future bioethanol demand, and the cellulosic biofuels technology is not yet mature. It is reported that China is importing more cassava[270], which might be part of the solution.

267 National Development and Reform Commission, 2016b, p. 20
268 China National Energy Administration, 2017
269 As reported by Sohu, 2017-02-17
270 Biofuels Digest, 2017-12-14

Mattias Goldmann

In-depth case study: Aviation

Rapid increase in flights, biofuels take off

In 2017, more than half a billion domestic and international flights were made in China, according to data from the Civil Aviation Administration of China (CAAC), with a year-on-year increase above 10% for the past several years. IATA predicts that China will surpass the U.S. as the world's largest commercial aviation market by around 2024[271].

Boeing estimates the total investment in new airplanes in China over the next two decades will be $1 trillion[272]. The state-owned Commercial Aircraft Corporation of China (Comac) is due to launch airplanes made for domestic aviation, which – given that most domestic airlines are state-owned – may take a sizeable share of the market, with export opportunities as well[273].

China's consumption of aviation fuel is about 20 million metric tons per year, with an estimated demand increase of 10% per year, more than double the global average and in contradiction to the International Civil Aviation Organization's (ICAO's) strategy for carbon-neutral growth[274]. The CAAC has set a target of reducing GHG emissions from aviation in China by at least 4% by 2020, compared with the 2011-16 period[275].

The rapid rise in Chinese aviation makes it important that emissions-reduction measures are taken, with the switch to biofuels being an important component. This would also lead to a reduction in oil imports, which would be beneficial to the Chinese trade balance and overall economy.

271 IATA, 2016-10-18
272 CNN, 2016-09-13
273 CNN, 2017-05-05
274 China.org.cn, 2014-02-12
275 Global Times, 2017-11-23

Globally, biofuels for aviation were approved for commercial use in July 2011[276] and in October 2011, Air China flew China's first flight using aviation biofuels: one engine ran on 50% biofuel from Chinese-grown jatropha oil supplied by PetroChina[277].

China's top oil refiner Sinopec started research on aviation biofuel in 2009, and its application for commercial use was accepted by the CAAC in 2012[278]. This makes China the fourth country in the world to produce aviation biofuel, after the U.S., France and Finland. Sinopec's production capacity is 3,000 metric tons of aviation fuel a year, from materials such as rapeseed, cotton seed and waste cooking oil, collected from restaurants. While this capacity is in itself low, corresponding to around 0.015% of total annual consumption, the actual production is currently even lower and seems to be done on a batch-by-batch approach.

China has very large quantities of used cooking oil (UCO), of which three liters can be converted into one liter of aviation fuel after collection, purification and processing. The UCO is particularly beneficial for biofuels, since this would mean that rather than the so-called "food versus fuel" conflict, this is clearly "food and fuel". Furthermore, since an existing resource is being used, the carbon footprint from the biofuel will be low – even though the high-altitude climate forcing from aviation is either only marginally reduced or not at all, implying that aviation needs to become more efficient and most likely to a large degree be replaced by other modes of transport[279]. As far as we have understood, there is no official policy or targets on the electrification of aviation. However, China is the home for several start-ups in this area. This includes the Chinese Academy of Engineering, which has presented an electric two-seater plane, and is currently developing larger models of electric planes[280] and Terrafugia, bought by Geely in late 2017, with the ambition to sell a flying electric car in 2019[281].

Any move to biofuels in aviation is expensive, given that conventional aviation fuels are not taxed. Sinopec's cost of aviation biofuels is up to three times more

276 Bloomberg, 2011-07-01
277 China Daily, 2011-10-29 and Air Transport World, 2014-02-14
278 Clean Technica, 2015-03-25
279 IPCC: Aviation and the Global Atmosphere
280 Defense World, 2017-11-04
281 IEEE Spectrum, 2017-11-14

than for jet fuel from crude oil[282]. For the biofuels to become viable in aviation and for the Chinese aviation increase to become more sustainable, China Energy Net Consulting calls for tax exemptions and subsidies for the aviation biofuels sector, in addition to regulations to ensure that UCO is collected and made available for fuel production[283]. If this happens, China could have an aviation-biofuels take-off that may be highly relevant for other countries to follow, given that aviation's current growth has until now not been matched by the rapid emissions reductions needed to reach the international climate targets agreed upon.

282 China.org.cn, 2014-02-12
283 China Daily, 2017-11-23

Jakob Lagercrantz

In-depth case study: Shipping

China has had a trade surplus for most of the past ten years, with the majority of the goods being shipped abroad from one of China's main harbors[284]. Five of the ten largest container ports in the world can be found in China, and the five largest Chinese carriers carry about one-fifth of the world's container shipping[285]. The Chinese-owned fleet has tripled in size since 2004, reaching 140 million gross tons in 2016. It is the world's third-largest fleet, shadowing Japan's and the world leader Greece. About a third of the fleet is sailing under other flags[286].

China is also expanding abroad, through investments and ownership of a large number of international ports. According to a Financial Times' review from January 2017, two-thirds of all global container traffic goes through Chinese ports, or ports with Chinese investment[287].

The expansion of the merchant fleet, with a yearly growth of approximately 10%[288], has also positioned China as a shipbuilding country. Many of the still few liquid natural gas (LNG) ships (methane-fuelled) ordered in the past years have been built in China, preparing for 2020 when the market is predicted to be at thousands of LNG ships destined for the international market[289]. LNG is one of the few alternative fuels currently available for the long-distance shipping industry and is opening up a path for renewable biogas. Other available biofuels, such as alcohols or biodiesel, will be part of the solution for reducing climate impact from the shipping industry, but the share scale of marine-fuel consumption means that demand for biofuels will rise in this sector.

284 Trading Economics, 2018-03-08
285 Financial Times, 2017-01-12
286 Hellenic Shipping News, 2017-03-30
287 Financial Times, 2017-01-12
288 Hellenic Shipping News, 2017-03-30
289 Wan et al., 2015

In 2007 the Sulphur Emission Control Area (SECA)[290] was introduced in U.S. waters and the North Sea/Baltic. In the SECA areas there is a limit to Sulphur contents in marine fuels. The limit is currently 0.1%. Beginning in 2016, the International Maritime Organization (IMO) NOx Tier III requirements were enforced in the U.S. emission control areas (ECAs), limiting also nitrogen oxides. The requirements will be enforced in European ECAs from 2021[291]. China has on a voluntary basis implemented a maximum-permitted marine Sulphur level in shipping fuels of 0.5%. This is still five times higher than the SECA limits, but it is a beginning of legal restrictions to polluting marine fuels. In China, ships in key ports in the largest rivers and the Bohai Sea Area need to use fuel with a lower Sulphur level (0.5%) when docked, in accordance with the Domestic Emission Control Area (DECA) regulations. By 2019, the voluntary DECA will be implemented to all operations in all ports in China[292]. The implementation of DECA started in 2016, and was then implemented in the ports of Shanghai, Nantong, Ningbo-Zhoushan, Suzhou and Shenzhen[293].

This is the beginning of controlling emissions from shipping and has been enforced by the Chinese authorities. In 2016, 55 out of 1,858 ships inspected by the Shanghai's enforcement agency were caught violating the Sulphur emission rules. This resulted in more than $100,000 in penalties. Furthermore, two ships, one of them foreign-flagged, were caught using fuels that didn't comply with emission standards two months following the phase-in of the regulations at four ports in Bohai Bay[294]. The enforcement will be strengthened in 2019 as DECA is expanded to all ships sailing in DECA waters[295].

In December 2017, China launched what has been called the world's first all-electric cargo ship. It is a 2,000-ton cargo ship, which will ironically be used to carry coal to industries along the Pearl River. It has a battery capacity of 2,400 kWh, the equivalent of 24 Teslas with the largest battery available, and can travel 80 kilometers at a speed of eight knots[296].

290 Annex VI of the 1997 MARPOL Protocol
291 Hellenic Shipping News, 2017-09-23
292 Climate Home News, 2017-04-20
293 Climate Home News, 2017-04-20
294 Climate Home News, 2017-04-20
295 Climate Home News, 2017-04-20
296 Electrek, 2017-12-04

China is now a global leader in many areas of environmental investments[297]. With the introduction of legislation limiting emissions from shipping, like DECA, and the increased importance of Chinese ship yards in the production of alternative fuel ships, there is a large potential for China to have an impact on global shipping. A uniform adoption of emissions-limitation rules throughout the Chinese coastal waters is an important step, but China still needs to enforce emissions regulation that is as strict as the ECAs in parts of the U.S. and Europe.

297 Deloitte Research, 2017

Mattias Goldmann and Jakob Lagercrantz

A policy comparison: Is China in the driver's seat and Europe hoping to catch a ride?

At the annual Swedish *Ekotransport* conference in April 2018, China was the focus country of the year. The Chinese delegation impressed the delegates with their strong aspirations and swift action. Several of the companies present at the conference did not even exist just a few years earlier, yet by today they are already multi-billion-yuan companies with extensive overseas operations. At the same time, the conference delegates realized that a lot of what is happening within the move to more sustainable mobility and transport in China comes out of necessity. The air quality in many cities is now so unhealthy that it has become a hindrance to economic development, much like the Los Angeles smog in the late 1940s, or the poor water quality in Stockholm forcing stringent mercury and heavy metal legislation in the 1970s.

But the means of change differ between the EU and China. In this chapter, we look at the different approaches towards sustainable transport. We focus primarily on the recent past and near future, with a strong emphasis on what has already been decided in contrast to what remain ambitions or forecasts.

The first and perhaps most obvious difference is on how decisions are made. China is a one-party society, with the Central Committee as the party's, and thus the country's, highest organ of authority, selected every five years at the National People's Congress. The Central Committee elects, in turn, the powerful politburo, with a standing committee, which is responsible for the major political decisions in the country[298].

298 Darlington, 2018

Prior to the formal decisions, the issues are debated internally between the different power centers in China, although with limited and largely unknown and undocumented consultations with, and input from, civil society and its organizations. There are merits in terms of a wide and predictable alignment of relevant policies and incentives, as can clearly be seen in the work to reduce the environmental impact from the transport sector since it became a declared priority in China in 2009. But there is also ample evidence from many countries that a free and open dialogue and a constructive exchange of ideas between the government branches and civil society has been beneficial to increase the speed of change towards a sustainable development, with more ideas and proposals to choose from, with the EU as a whole and Sweden in particular, as examples.

Learning from China

With these and other differences in mind, we see five main areas where the EU and individual European countries could learn from China:

1. **Long-term targets and continuous adjustments.** The long-term targets are essentially a consequence of the political structure of China and how they work with five-year plans, but the overarching goals have been combined with more detailed plans for major sections of the general plan, and continuous adjustments to help ensure the targets are met. While this approach can, to a large degree, be characterized as top-down, it also holds elements of entrepreneurship that need to be understood in order to fully grasp China's development. This combined approach is in line with how the European and American markets that have been the most successful in increasing the share of low-emission vehicles have behaved, and should serve as inspiration for others.
2. **Shared mobility to reduce congestion**. We see a swift development in Chinese cities, where shared mobility services – such as public transport, ride-sharing, car-sharing and bicycle-sharing – are becoming a

necessity for a long-term sustainable development. The world's largest ride-sharing services, the largest fleet of shared bicycles and many other initiatives mean that there is a lot to learn from for European legislators at both national and local level. This includes how to best combine shared services with digital solutions, how to combine the massive introduction of free-roaming shared bicycles with accessibility and walkability in city centers, and how to ensure that ride-sharing becomes a driving force for speeding up the move to cleaner vehicles.

3. **Linking benefits to range performance.** The current Chinese NEVs subsidies are linked to the electric range of BEVs or PHEVs. Below a certain mileage on electricity, the vehicle is not eligible for any subsidies, while NEVs with a longer electric range get a higher subsidy, with specific subsidies for local battery production as well. This encourages the development of vehicles suitable for more users and limits the percentage that PHEVs are run on petrol or diesel, thus improving air quality and reducing the climate impact of these vehicles. Most other markets lack this structure of incentives and may consider them, for instance, as a stepping stone towards a cost-neutral system or a quota-based system.
4. **Cities as drivers for change.** In both China and now Europe, cities are requiring policy change in order to improve air quality for its citizens. With a dire air-quality situation, cities like Beijing are implementing radical solutions like rationing and lotteries for combustion-engine vehicles, city closures one day per week for all cars depending on the registration plate number, banning of combustion-engine scooters and incentives for bicycles and EVs. A success story worth mentioning is the very rapid introduction of electric buses in many Chinese cities, with Shenzhen as the first city in the world to fully electrify its entire public transport fleet. In several European countries, cities could benefit from a strengthened and more systematically enforced subsidiary principle, which also serve as a strong basis for increased cooperation directly between Chinese and European cities.

5. **Quotas for EVs.** Under the dual-credit system, car manufacturers are required to sell a certain and increasing percentage of NEVs, starting with 8% in 2018 and rising to 12% in 2020[299]. These quotas are at least in theory tradable, meaning that companies that perform better than they are legally required to do can sell the surplus to other manufacturers. This system, similar to what is already in place in California, lowers the total cost of introducing EVs, but also creates an additional incentive for car makers to be on the receiving end of the system. European countries may consider moving out of subsidy schemes that are bound to become costly as sales of electric vehicles increase, and learn from the Chinese way of ensuring NEVs market growth at no cost to the state.

China learning from Europe

We also see five main areas where the Chinese could learn from European countries:

1. **Ensure that alternative fuels, including electricity, are renewable**. In China, electricity is still around 70% dependent on coal, even though the rate of solar and wind power is increasing quite rapidly[300]. For liquid fuels, the rate of renewables is still very low, particularly on the diesel side, even though the potential for using waste material is very large.
2. **Energy efficiency targets and emphasis.** While China has a clear CO_2 reduction target from the transport sector, there is a limited focus on energy efficiency. The targets for increased efficiency under the 12th FYP were not met[301], while in the current FYP, the goals for energy efficiency are clearer, but focus mainly on carbon intensity in the energy sector[302]. While the targets are a positive step forward, in the transport

299 Manager Magasin, 2017-02-06
300 See also Chen, 2018
301 Radio free Asia, 2013-11-11
302 Reuters, 2016-03-15

sector they are not as clear, ambitious or well-established as they are for the EU and its member countries, including Sweden doubling the energy efficiency per currency unit between the years 2005 and 2030[303].

3. **Emphasize and use national/regional differences.** All countries do not have the same possibilities, and all regions in China do not have the same resources. While the EU is much less of a shining example than the U.S. and its states, the EU does allow for different strategies. This has meant that member states have come up with different solutions that have then been adopted in other parts of the EU, for vehicle taxation, biking incentives, aviation biofuels and many other areas.
4. **Include heavy vehicles.** China has come a long way in developing electric trucks, with several thousand on the road, but the environmental performance of conventional trucks is not as impressive as the Euro-classification and the upcoming CO_2 directive for trucks in the EU. Furthermore, individual EU countries like Sweden have strong policies and incentives for the usage of sustainable biofuels in trucks, which may be relevant for China to study.
5. **Sustainability targets for batteries, biofuels and components.** China is one of the battery superpowers. Sustainability is often a requirement from the large western car companies purchasing batteries, but China could sharpen domestic requirements on sustainability on this very central part of the sustainable life cycle of an EV. We also encourage strong domestic sustainability criteria for other components of the vehicles, as well as for biofuels. Here, European countries can show how agricultural production is increased at the same time as biofuel production increases, and how agricultural and forest residues can be used for fuel production.

303 Regeringen, 2016-11-28

Julia Hansson

Fact box: Nordic policy perspective

Transforming transport in order to reach sustainable mobility is also the next big energy challenge in the Nordic region. Achieving the ambitious climate change mitigation targets for the transport sector decided by Nordic governments will be challenging, and the work will benefit from an international outlook as well as national measures (IEA/NER, 2013). Some reflections from a Nordic policy perspective, expressing the views of the Shift (Sustainable Horizons in Future Transport) project financed by Nordic Energy Research, follow.

The promotion of EVs in Norway through broad governmental financial support, to some extent similar to Chinese efforts (and potentially inspiring the Chinese development) has spurred the introduction of electric vehicles, leading to EVs representing 50% of new car sales in Norway. In the Nordic countries, like in China, the development of low-emissions heavy transport such as the electrification of long-haul freight, including shipping, needs to be further promoted.

Due to infrastructure measures and vehicle charges, 62% of the inhabitants in Copenhagen, Denmark choose bicycles for travel to work and education, and bicycles represent 50% of transport in the Danish capital. From this perspective, the development of bicycles and bicycle-sharing in China is inspiring.

In Sweden, sustainably produced biofuels have played an important role in the move towards a more sustainable transport system, and the quota system for biofuels that will be implemented on July 1, 2018 requires that the climate impact from transport fuels is reduced over time, further promoting advanced biofuels produced from residues and waste. The contribution of sustainably produced biofuels could increase also in China.

Similar to Chinese cities, the Nordic region can and may act as a test-bed for exploring sustainable mobility solutions. As in China, different busi-

ness models for car-sharing and ride-sharing are being tested in the Nordic countries, as well as developments within public transport. Electric bicycles have also been introduced partly as the result of national policies, for example in Sweden.

Competing for the common good

The purpose of this report, and of the 2030 secretariat's focus on China, is to learn from China's advancements, but we have also seen that there are areas in which China can learn from Europe – which in turn increases the opportunities for a mutually beneficial exchange. In some areas there is no clear sense of leadership, meaning that China and Europe can cooperate and develop the path ahead together – or choose to compete to spur faster development towards sustainability. We see five areas where this may be particularly true:

1. **Production capacity.** With a predicted rapid increase in demand for electric vehicles, from electric bicycles to cars, buses, trucks, ferries and potentially aviation, the demand for batteries is expected to surge. According to many predictions, including Moody's Investment Services report from the spring of 2018, this will lead to a shortage of production capacity, for batteries and/or for individual components or raw materials for them, such as cobalt, copper or nickel[304]. Until now, many manufacturers of the vehicles have deemed that the batteries fall outside of their core competence, and will thus rely on suppliers, most of them until now found in China and South Korea, though some have a share from American and European companies as well. The predicted shortfall could also be alleviated through increased recycling of existing batteries, which has until now only been practiced on a small scale. In this endeavor, Chinese and European interests could merge, which would reduce the risk of the very substantial investments needed, although with continued competition with the end-products.

304 Mining, 2018-05-01

2. **Autonomous vehicles.** There is intense competition in the development of autonomous vehicles, which is at least as relevant and important for heavy-duty vehicles, including shipping and aviation, as it is for passenger cars. The Chinese strategy for artificial intelligence is impressive in both its detail and determination, and may in many respects function as a benchmark for European ambitions and for continued competition, which we encourage since we believe it will speed up development.
3. **Business models for shared mobility.** Chinese cities are an excellent development area for shared services. The sheer number of people, more than 20 million in greater Beijing alone, allows for testing and development of initiatives. Europe may struggle to find the same momentum, but should aim to help businesses develop strong, solid business models for shared mobility and create economic incentives that encourage the shift.
4. **Green aviation.** China aims to be a significant market player in civil aviation and has strong ambitions for more sustainable flights – which in turn is urgently needed given how quickly aviation is increasing in China. The European aviation industry may focus on competing with the Chinese on sustainability, and European aircraft buyers and national aviation authorities may economically encourage the rapid development of sustainable bio-based jetfuel and the electrification of aviation, since there is also a strong need to reduce GHG emissions from the aviation sector in Europe.
5. **Railroad.** The Chinese focus on high-speed trains, now being built across China, is matched by an increased emphasis on freight trains, including the recently inaugurated freight line between China and Europe. In several countries within Europe, we are also seeing a reborn interest in the railroad, spanning from commuter trains to new high-speed lines and freight on rail as a way to reduce congestion on roads. Chinese companies in the railroad sector are present on several European markets as operators of public transport, and are interested

in tendering for railroad construction in European countries with ambitions to increase their networks. We believe this may be a basis for cooperation towards an increase in rail's share of total transport.

Overarching conclusion: Becoming world leaders in sustainable mobility

A decision and a vision could be the difference between success and mediocre development. China decided in 2009 to become world leader in NEVs, and it is well on its way, with the largest market in the world and currently more than half of worldwide EV sales. Several European countries have similar targets and impressive achievements in terms of market share. But the global race for leadership in sustainable mobility has only just started, and the more intense it gets, the better for local air quality and health and for the global climate. In many areas, China and Europe would mutually benefit from increased cooperation, while in some areas, the competition itself will be a strong driver for improved solutions and reduced emissions.

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Frank Yang · Mattias Goldmann · Jakob Lagercrantz

Sustainable mobility the Chinese way

Opportunities for European cooperation and inspiration

China has the world's largest emissions of greenhouse gases, the biggest market for passenger cars, the most rapid growth in bicycle-sharing and the toughest targets for electromobility. It combines a state-controlled system with market incentives, linking overarching long-term targets with continuous legislative updates and revisions of incentives.

The purpose of this publication is to give a better understanding of China's work for sustainable mobility, as well as the underlying motives for the country's development in this area. It's written for policymakers, academia and businesses, as inspiration within the area of sustainable mobility, but also with the aim to give a critical and balanced perspective. Our aim is further cooperation with China when it is appropriate, and competition when it is advantageous.

ISBN 978-9-1873794-5-1