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## Summary

Energy and environment have become key issues facing all countries in the world. China is in the pathway of rapid social and economic development, energy and environmental issues, therefore, are of particular importance. In China, both the central and local governments have taken a lot of efforts to promote the development or spread, such as clean vehicle: battery electric vehicle (EV), hybrid electric vehicle (HEV), fuel cell vehicles (FCV), and alternative fuels, such as: ethanol, methanol. But if these efforts would receive expected pay-offs? Would policy work as planned? If it will, is the outcome what they want, or there is other side effects unexpected? Addition to that, in the previous work much attention is paid to electric vehicle industry, most of them give insights on development of technology and life cycle analysis, however, few efforts have been given to policies, technology trend and interaction among users, especially for China, a country of huge demand for clean alternative vehicles. Thus following the main question for this study: ***What are the scenarios for electric vehicles' transition in China?***

Transition involves not only new technologies but also in the user's practice, legislation, policy, infrastructure, networks and institutional change. A method called socio-technical scenario (STSc), which is designed with consideration of the dynamic nature of technological transition is conducted in this research. A STSc is a story that describes possible future developments, making use of the patterns and mechanisms<sup>1</sup> (Elzen, Geels, & Hofman, 2002). STSc method is based on what we call the *transition theory*. This theory builds upon insights from the domain of *Science and Technology Studies* (STS) that emphasizes the interrelatedness between technical and social change (Elzen, Geels, & Hofman, 2002). STS analyses how technology is shaped by social, economic, cultural and political forces as well as how new technologies shapes society and the interaction between various actors.

At the heart of the transition theory are three 'levels' and the interactions between them (the *multi-level* perspective; Kemp, Rip and Schot 2001). These levels are: 1. The *socio-technical landscape*: this describes broad processes and factors in society (e.g. cultural developments, climate policy) that affect a wide range of developments; 2. The *socio-technical regime*: a specific sector of society of interest to the analyst (in our case traffic and transport). Regimes describe the interrelation between technology, policy, user preferences, infrastructures, etc. 3. *Technological niches*: 'alternative' technologies that hold a promise to play a role in the regime but that cannot compete (yet) with existing technologies. This is partly an economic issue but it also requires tuning of a variety of technical and social factors including infrastructure requirements, user preferences, policy, etc. In niches, learning processes and interactions between actors are keys.

And in order to structurally interpret regime transformation, another approach is adopted, a quasi-evolutionary model of socio-technical transitions proposed by Smith (2005) is described in which regimes face selection pressures continuously. Smith (2005) suggests that regime transformation processes can be organized according to whether they contribute to the articulation

of selection pressures (exerting pressure for change), or whether they contribute to the adaptive capacity (resourcing and coordinating a response to this pressure).

With regard to the methodologies and theories, the main question in the study can be decomposed into three sub-questions, so each of them can be dealt with specifically and individually. They are the theoretical questions: *To what extent do transition theories and methodologies apply to China?* And empirical questions: *Who are the actors that possess significant influence in the transition of electric vehicle in China?* Besides that, *how do actors, interact in the present socio-technical system in China with respect to the case of EV's (and within the case of electric bikes and scooters)?* Last but not least the prescriptive questions: *What recommendation can be given to China's government on the development of EV based on this study and the socio-technical scenarios developed?*

For the theoretical question, transition theories are examined and through its application method Socio-Technical Scenarios (STS) in China's context. To provide more insights of applying transition dynamic theories to China, two approaches were conducted. Firstly, By reviewing previous work based on transitions theory and multi-level perspective focusing on western society to identify similarities and differences between these societies and China, which might result in diverse research outcome. Transition theories have been widely used in field of technological change of social function, and some brilliant works have been done on the potential of electric vehicles' transition mainly in western societies. Some important notions and shared similarities have been found among different socio-technical scenarios. And some basic structures of actor network and socio-technical system are generally agreed upon. However, potential diverges do exist between context of western societies and China, especially in policy aspect, which will result in a potentially influencing difference in actor network and socio-technical system. Thus another approach emerges, that is a case study conducted in the very context of China with STSc will help us gain more insights into this field.

In this part, E-bike's large scale introduction in China will be examined and studied through application of STSc method, which is expected to have three contributions to this paper. The first one is that it complements our knowledge about the dynamic interrelation between the landscapes, regime and niche development in the very situation of China, which also contribute to answer the practical sub-research question we have at the beginning. Another purpose of this study is to examine the theory itself in its application, so to speak, to gain more insights of the theoretical question that to what extent this method could be applied. The last but not least, to answer the question what is the role of electric two wheels in the transition of electric vehicles and under what conditions. Importantly this method is adapted through the case study of e-bike and implemented in the socio-technical scenarios of electric vehicles.

For the empirical question, analysis will focus on the field of electric vehicle in the context of China based on multi level perspectives, respectively, landscape, regime and niche developments. In the landscape analysis, landscape factors may influence the dynamics at the regime and niche levels, as

well as the possible interactions between them. That's why the goal of this step is to identify significant landscape features such as geo-political dimensions, related policies, as well as economic and environmental issues, where driving forces for this transition emerge. Pressing needs of solving environment and energy issues have been expressed from different aspects of China. No policy regarding to these problems is not a viable option for a sustainable future of China. Potentials are also shown in the study, especially in field of sustainable energy development. With tremendous effects of each factors in the study, an implication of huge difference between different socio-technical scenarios basing upon various options and directions are confirmed.

For the regime development analysis, according to the transition theory, when landscape factors put pressure on the existing regime, 'windows of opportunity' may open up, increasing like this the chance for radical innovations to break through. Therefore, a transition processes demands the analysis of the existing system as well as the understanding of how this system has been created in the recent past. This analysis thus tries to identify major characteristics and trends in the regime, including main actors, patterns and possible tensions that could provide linkages to niche developments. Through socio-technical system, a general picture is depicted for electric vehicles' regime. And the corresponding social group network emphasize on activities and influence of each actors. A group of key actors emerge from the general picture, and some interrelations of them are further elaborated. Carmaker-consumer relationship and local government-industry relationship are analyzed through several characteristics, which constitute important factors of socio-technical scenarios of this study. In the exchange of consumers and car manufacturers display some typical behavior patterns, it has been institutionalized. These patterns can be categorized as regulative, normative and cognitive rules. This study describes three relationship patterns of behavior between car manufacturers and consumers. To get more insights into knowledge, attitudes and expectations in this relationship, an interview is conducted in this research among the general public audience of *2010 Beijing international automotive exhibition*. This insight serves as a basis for further analysis of actors, rules, socio-technical system and their interaction. The basic structure of this interview is based on the analysis by R.R. Heffner et al. in 2007, *Symbolism in California's early market for hybrid electric vehicles*. With an adaptation to China's situation, that few HEV or EV adopters can be found, the interviewees in this analysis would be potential auto buyers with various interests, and this exhibition would be a good opportunities to find them. 18 feedbacks are collected, and two of them are chosen to display in this report. Although individual preferences are diverse in the interviews, some general points shared by almost all the participants also emerge, especially in comparison with the results of the previous interviews in the US. In the relationship between local governments and industry, institutions at the local level will often determine the success or failure of development efforts (Segal, Thun, 2001). Local government as the intermediate between many elements (user, carmaker, central government), is crucial to transition of EV. Thus a local government-carmaker or local government-industry analysis will help to identify dynamic trends of scenarios. This study has

looked from both perspectives of the local government and the industry to find their behavioral pattern, motivations and barriers they have encountered in their real world practices.

Following is the niche development analysis, in order to find the niche that together with landscape factors put pressure on the existing regime to create 'windows of opportunity'. An examination of radical innovations that owns potentials to break through is important to the overall study. Fuel cell vehicles (FCV), battery electric vehicles (BEV) and hybrid electric vehicle (HEV) as possible options are studied through their technical attributes and their individual barriers to surmount. Besides that descriptions of the technological niches, including the recent dynamics, current status and future potentials, alternative technological forms, the possible markets, a brief history of the niche, costs, barriers, user preferences, policies, dimensions concerning market, production and infrastructure are also included in the study.

For the prescriptive questions, four scenarios are introduced in this research for future electric vehicles' developments in China, and they are based on the multi-level perspective research, which involves landscape development, socio-technical regime developments and niche developments of electric vehicles. Driving forces and other important factors have set different trajectory for the overall structure of each scenario. Concern for energy security and environmental problems are considered major driving forces for transition of electric vehicles to take place. For local governments' administration pattern, their relationship with industries play an important role, which are categorized as either horizontal pattern or vertical pattern. In the comparison of different scenarios, one can notice that different driving forces are responsible for the major differences in scenarios. Since the initial objectives are different, the whole situations are sent on various trajectories.

In this research, insights are obtained from three different angles. The first one is exploration of transition theory and STSc's application in China especially for transport sector. The second one is interactions among active and essential actors in socio-technical regime revolve electric vehicles. The third one is recommendations for China's future developments of electric vehicles based on comparisons made between different socio-technical scenarios.

Essentially, transition theories are broad and robust enough to cope with varieties of situations, in which China's context included. However, when it comes the methodologies based on transitions theories, minor adjustments can be suggested. In the context of China ever since 1980', the regime level interact with the landscape level intensively, and much more 'window of opportunities' emerged than it is usually expected. Under such circumstances, many socio-technical transitions did not try to entrench silently within the orders, but take advantage of the dynamic environment rise altogether with it. Traditional transitions theories cannot be applied to China in the dynamic period without consideration of the phenomenon described above. Quasi-evolutionary model of socio-technical transition is adopted in this research. However, criticism of this method is also discussed 'every transition becomes coordinated at some point through the alignment of visions and activities of

different groups' (Geels, Schot, 2007). Thus, I propose a model with more focus on the coordinated response side of the axis to adapt to the situation of China.

For the interactions between regime actors, local governments' administration pattern towards industries have been classified as horizontal and vertical pattern, Beijing and Shanghai are illustrated as representatives respectively. For consumers, an interview is made to evaluate the public's attitudes towards conventional vehicle and electric vehicle. Although the number of subjects is not enough to draw significant conclusion on electric vehicles' public acceptance, some general characteristics can be obviously observed as foundation for the study. Local government-carmaker relationship and consumer-carmaker relationship are identified as important and illustrated precisely. However, there are still other relationships worth looking into closely in the future analysis, which are not conducted due to the scope of this study.

Development of electric vehicles in China is considered as a successful solution for energy and environment problems. From this perspective, promotion of electric vehicles' development in China is rewarding and should be recommended. However, some important implications have been derived from the scenarios, which are not to be ignored in case to achieve a sustainable future for China and the world.

#### ENVIRONMENT SUSTAINABILITY COMES FIRST

It is obvious from comparison between scenario 1 (1A &1B) and scenario 2 (2A &2B), that the environmental problems ended differently in the given time frame. From another perspective, improving environmental sustainability helps solving other pressing issues as well.

#### PUBLIC TRANSPORTATION AS AN OPTION

With the fact that promotion of electric vehicles alone will be facing many problems and an important one of them is the transportation pressure, especially in China, a country with huge population. This phenomenon suggests that public transportation can be adopted as an option to help alleviating mobility pressure of the cities in the process of electric vehicles' transition.

#### BE CAREFUL WITH FUEL EFFICIENCY REGULATIONS

No doubt fuel efficiency regulation will expedite the process of technology accumulation and transfer, and improve air condition of the cities in the short term. However, from a long orientated point of view, the ever rising bar of fuel efficiency tends to increase problems in many ways. Clear objectives, possible negative consequences are imperative to policies' formulation and implementation.

#### TRANSITION MANAGEMENT IS A KEY ROLE

As depicted in scenario 1B, a successful niche market is developed by the joint effort of local governance and external regime, where new standards for electric vehicles come into play instead of extension of conventional vehicles. The technology gap between EV and E2W are huge, this transition



will not be achieved without the help of external group (the governments) to provide important resources, capabilities and networks.

#### START THE REINFORCING CIRCLE

In previous work, endogenous dynamics have primarily been captured by analyzing the chicken-and-egg problem (McDowall, 2006). It is recommended for the government to move first in this system, since both manufactures and the public lack a long oriented consideration for a sustainable future.

## 简介

能源与环境已成为世界面临的所有国家的关键问题。中国正处于迅速的社会和经济发展的途径，能源和环境问题，因此，特别重要。在中国，无论是中央和地方政府采取了一系列努力，促进发展或蔓延，如清洁车，很多：电池电动汽车（EV），混合动力电动汽车（HEV），燃料电池汽车（燃料电池汽车），以及替代燃料，如：乙醇，甲醇。但是，如果这些努力将收到预期的支付班次？将政策工作按计划进行？如果会，结果是他们想要的，或者有其他意想不到的副作用？此外，在以往的工作相当重视电动汽车产业，其中最让对科技和生命周期分析的发展的见解，但是，很少的努力已获得的政策，技术趋势，互动用户间特别是中国，一个为清洁燃料的车辆巨大需求的国家。因此，继本研究的主要问题：什么是'电动汽车在中国转型期的情景？

转型不仅涉及新技术在用户的做法，立法，政策，基础设施，网络和体制的转变，而且。一个方法调用社会技术方案（Socio-technical scenarios, STSc），这是同技术过渡性质的动态设计的出发点是本研究进行。一个科技小组委员会是一个故事，描述未来可能的发展，利用的模式和机制（Elzen, Geels, & Hofman, 2002）的使用。科技小组委员会的方法是基于我们所说的过渡理论。这一理论是建立在从科学和技术研究（STS）的，强调技术和社会之间的变化（Elzen, Geels, & Hofman, 2002）的相互关系领域的见解。社会技术方案是如何形成的社会，经济，文化和政治力量，以及如何利用新技术的形状和社会各种行为者之间的互动分析。

过渡时期理论的核心是三个‘层次’和它们之间的关系（the multi-level perspectives; Kemp, Rip and Schot 2001）。这些级别是：1 社会经济景观：这个过程描述了广泛的社会和因素（如文化的发展，气候政策）影响广泛的发展；2 在社会技术制度：一个社会的利益的具体部门在我们的案例分析（交通运输）。制度之间的描述技术，政策之间的相互关系，用户的喜好，基础设施等 3 科技利基：'替代'技术，拥有一承诺制度中发挥作用，但不能竞争（但与现有技术）。这部分是一个经济问题，但它也需要在技术和社会因素，包括基础设施的要求，用户偏好，政策，壁垒等，学习过程和演员之间是互动的各种调节键。

另外，为了解释政权结构转变，另一种方法是通过一个由史密斯提出的社会技术的过渡（2005年）中描述的政权面临选择压力不断准演化模型。史密斯（2005）认为，体制转换过程中可以组织根据它们是否有助于选择压力（施加变革的压力衔接），或者他们是否有助于适应能力（资源和协调，以这种压力的反应）。

关于方法和理论，在研究的主要问题可以分解为三个子问题，所以他们每个人都可以与具体和个别处理。他们的理论问题：在何种程度上转变理论和方法适用于中国？并：经验问题谁是演员拥有的在中国电动汽车过渡重大影响？除此之外，如何做演员，在目前的社会技术系统在中国方面互动的案例电动车（和范围内的电动自行车和滑板车的情况下）？最后但并非最不重要的是：规范的问题可以给出什么建议对电动汽车的发展，中国政府在此基础上研究和社会经济发展的技术方案？

对于理论性的问题，过渡理论是研究和应用方法，通过其社会技术（STS）在中国情景的应用的。为了提供应用过渡到中国更多的动态理论见解，有两种方式进行。首先，通过回顾以往工作的基础理论过渡，多层次的角度对西方社会的关注，以确定这些社会之间的异同和中国，这可能导致不同的研究结果的差异。转型的理论已被广泛应用于社会功能领域的技术变革，和一些精彩的作品已对电动车进行过渡潜力主要在西方社会。一些重要的概念，并发现了共同的相似之处，不同的社会和技术方案。和演员网络和社会技术系统的一些基本结构一般是商定。但是，确实存在潜在的发散与西方社会和中国，特别是在政策环境方面，这将导致在演员网络和社会经济系统的潜在影响的技术差距。因此出现了另一种方法，这是一个案例研究与中国的科技小组委员会范围内进行将非常有助于我们加深对这一领域的更多的见解。

在这一部分，电动车在中国大规模引进将审查并通过社会科技情景的方法，预计有三大贡献本文应用研究。第一个是它的补充，我们对相互之间的动态环境，制度和在中国，其中也有助于回实际调研的问题我们在一开始有非常情况利基发展的知识。本研究的另一个目的是审查其申请的理论本身，这么说吧，以获得更多的理论问题的见解，在何种程度上这种方法可以适用。最后但并非最不重要的，回答的问题是什么，在电动汽车过渡的作用电动两轮，在什么条件下。更重要的是这种方法是通过个案研究适应电子电动自行车和电动汽车的社会技术方案实施。

对于经验性问题，分析将集中在中国范围内的电动车领域的多层次的观点，分别加工，制度和特殊的发展。在景观分析，景观的因素可能会影响在各级政权和生态位的动态，以及它们之间可能的相互作用。这就是为什么这一步的目的是要确定，如地缘政治方面，相关政策，以及经济和环境问题，重要景观特色的地方，该过渡时期出现的驱动力。解决迫切的环境和能源问题的需要，有人从中国的不同方面。没有关于这些问题的政策是不一对中国可持续发展的未来可行的选择。潜力还表现在研究，特别是在可持续能源发展领域。由于在研究中，不同社会之间，在各种方案的技术基础和方向，每个场景蕴涵的巨大差异巨大的影响因素确定。

对于这一制度发展的分析，根据过渡理论，当景观因素对现行制度的压力，'机遇'可以打开窗户，这样增加了根本性创新突破的机会。因此，过渡过程要求对现有系统的分析，以及关于如何计算这一制度已在最近成立的了解。因此，试图以这种分析确定主要特点和趋势的制度，包括主要演员，模式和可能的紧张关系，能够提供的联系，以利基发展。通过社会技术系统，一般的图片描绘的电动车制度。和相应的社会团体的活动和网络强调每个演员的影响力。集团的重要行动者摆脱一般的图片，其中有些相互关系进一步阐述。汽车制造商与消费者的关系和当地政府及业界的关系进行了分析，通过几个特征，构成本研究社会技术方案的重要因素。在消费者和汽车制造商的交流展示一些典型的行为模式，它已被制度化。这些模式可以被归类为调节，规范和认知规律。本研究介绍了三种汽车制造商之间的关系和消费者的行为模式。进入知识更多的见解，在这种关系的态度和期望，在接受采访时进行这项研究在一般的2010年北京国际汽车展览会的公众观众。这种认识作为一个演员的进一步分析的基础上，规则，社会技术系统及其相互作用。这个面试的基本结构是基于由 R.R. Heffner et al. (2007)，在加利福尼亚州的早期市场象征混合动力电动汽车。随着对中国的情况适应，很少采用混合动力汽车或电动汽车可以发现，在这一分析的受访者会与各种利益的潜在汽车买主，这个展览将是一个很好的机会找到他们。18 收集反馈，其中两个是选择显示在这个报告。虽然个别的喜好在不同的面试，一些一般性的意见分享，几乎所有的与会者也出现，特别是在与美国前采访的结果进行比较。在当地政府和工业界之间，在地方一级机构的关系，往往决定成败的发展努力(西格尔，图恩，2001年)的失败。地方政府之间的中间许多元素(用户，汽车制造商，中央政府)，是很重要的电动汽车过渡。因此，一个地方政府的汽车制造商或当地政府，行业分析，将有助于查明情况的动态趋势。本研究曾研究从两个角度当地政府和业界发现他们的行为模式，动机和他们在现实世界中所遇到的障碍的做法。

以下是利基发展的分析，以便找到的科技萌芽，共同与景观方面的因素使对现有政权施加压力，以制造机遇。一个拥有潜力，突破创新，激进考试是重要的整体研究。燃料电池汽车(FCV)，尽量选择电池电动汽车(BEV)和混合动力电动汽车(HEV)进行了研究，通过他们各自的技术特征和克服障碍。此外，该技术利基说明，包括最近的动态，现状和未来潜力，替代技术的形式，可能的市场，一个简短的历史定位，成本，障碍，用户偏好，政策，尺寸有关市场，生产和基础设施也包括在研究。

对于规范性的问题，介绍了四种情况在中国这个未来电动车发展的研究，他们是多层次的角度研究，其中涉及景观发展，社会基础技术体制的发展和电动汽车的发展利基。驱动力和其他重要因素，为每个情景整体结构不同的轨迹。对能源安全和环境问题的关注被认为主要用于

电动汽车的过渡动力发生。对于地方政府管理模式，他们与产业发挥了重要作用，这是因为无论横向模式或纵向模式分类的关系。在不同情况下的比较，人们可以看到，不同的驱动力是在方案的主要分别负责。由于最初的目标是不同的，整个情况是不同的轨道上发送。

在本研究，见解是从三个不同的角度。第一个是过渡的理论和科技小组委员会在中国的应用探索，尤其是运输部门。第二个是在社会经济中，围绕电动汽车的技术体制和必要的积极行动者的互动。三是不同社会之间的技术方案作出比较基于中国电动汽车的未来发展提出建议。

从本质上讲，过渡理论是广泛和强大，足以应付局势品种，其中中国的情况包括在内。然而，当谈到关于过渡的理论为基础的方法，可以轻微的调整建议。在中国自从 20 世纪 80 年代背景下，该制度层面互动的景观层次深入，以及更多'机会'出现了比通常预计的窗口。在这种情况下，很多社会技术的过渡没有试图巩固在默默的命令，而是采取了动态环境中崛起与它完全的优势。转变传统理论不能适用于动态时期中国没有上述现象的考虑。准进化的社会技术转移模型，采用本研究。然而，这种方法的批评，并讨论'每过渡成为在某个时候通过协调不同的看法和团体的活动路线'(Geels, Schot, 2007 年)。因此，我建议更多的轴侧重点的协调一致的反应模式，适应中国的情况。

演员之间的制度，地方政府对行业管理模式的互动被列为横向和纵向模式，北京和上海为代表，分别说明。对于消费者来说，接受采访时作出评价实现传统汽车和电动汽车的市民的态度。虽然在一些科目是不够的，利用电动车市民的接受程度显著的结论，一些一般性的特征可明显观察为基础的研究。在地方政府的汽车制造商和消费者的关系，汽车制造商的关系确定为重要的，恰恰说明。不过，仍值得密切关注未来的分析，这是由于没有进行这项研究的范围到其他关系。

电动汽车的发展被认为是中国对能源和环境问题的成功解决方案。从这个角度来看，电动车在中国的发展是有益的促进，应该建议。但是，一些重要的影响已被来自的情景，这是不能被忽略的情况下，实现了中国和世界的可持续发展的未来。

### **环境的可持续性优先**

很显然，从方案 1 之间的比较（1A 及 1B）及方案 2（2A 及 2B），即环境问题结束了在给定的时间框架是不同的。从另一个角度来看，改善环境的可持续性有助于解决其他紧迫问题以及。

### **公共交通作为一个选择**

事实上，随着电动汽车的推广仅将面临许多问题和其中的一个重要的是运输的压力，尤其是在中国，一个人口众多的国家。这种现象表明，公共交通，可作为一种选择，以帮助缓解流动性的电动车过渡过程中的城市的压力通过。

### **小心燃油效率规例**

毫无疑问，燃油效率规例将加快技术积累和转移的过程，改善空气在短期内城市的条件。但是，从长远的角度导向来看，不断上升的燃油效率提高酒吧往往在许多方面的问题。明确的目标，可能产生的消极后果是必要的政策的制定和实施。

### **过渡管理是起到关键的作用**

正如方案 1B 款，一个成功的利基市场，所描述的发展由地方管理和外部的制度，其中电动车的新标准将取代传统的车辆延长发挥作用的共同努力。EV 和 E2W 之间的技术差距是巨大的，这种转变将离不开外部组（政府）提供重要的资源，能力和网络的帮助。

### **启动循环**

在以前的工作，内源动力已被捕获，主要通过分析鸡和蛋的问题（麦克多沃尔，2006）。这是建议政府朝此系统的第一个，因为两个生产和公众缺乏长期可持续发展的未来导向的考虑。

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# 1 THE INTRODUCTION OF ELECTRIC VEHICLES IN CHINA

## 1.1 PROBLEM CONTEXT

Energy and environment have become key issues facing all countries in the world. China is in the pathway of rapid social and economic development, energy and environmental issues, therefore, are of particular importance. In China, both the central and local governments have taken a lot of efforts to promote the development or spread, such as clean vehicle: battery electric vehicle (EV), hybrid electric vehicle (HEV), fuel cell vehicles (FCV), and alternative fuels, such as: ethanol, methanol. But if these efforts would receive expected pay-offs? Would policy work as planned? If it will, is the outcome what they want, or there is other side effects unexpected? In this chapter, I would first look into current technology knowledge and policy that has been or about to implement in this field, then propose the questions I would like to research in this paper.

In the current mode of motorization in China, there will be a remarkable increase in vehicle stock and on-road vehicle fuel demand. By 2030, the total vehicle population might be 400 million (including 150 million motorcycles and rural vehicles), and the fuel demand 350 million tons. At the same time, an optimistic forecast with domestic oil production declining gradually, by 2030, the aggregate domestic oil production would not satisfy half the total on-road vehicle demand (Hu et al., 2009).

To address these issues, the Chinese Government has put efforts into policy formulation and implementation activities to help alleviate possible impacts of the social and economic systems. Promoting development and dissemination of clean vehicles and alternative fuels (Thomas, 2009) is one of the strategies. Technology is an important factor in this problem. What is an electric vehicle (EV)? It is a vehicle which uses one or more electric motors for propulsion. Electric vehicles are different from fossil fuel-powered vehicles in that they can receive their power from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable. The electricity may then be stored onboard the vehicle using a battery, flywheel, super capacitor, or fuel cell (Fuji time online, 2010)

There is no absolute consensus on what kind of electric vehicles would be dominant in the future market. According to some analysis only pure BEV and FCV should be considered as solution to environmental problem and energy scarcity in the long term (Offer et al., 2010). They present differences in attributes such as range, efficiency, cost, and recharging methods. In addition it is essential to consider the relevance of the technologies to the application. Another option is explored: fuel cell hybrid electric vehicle (FCHEV), and which seems to perform better energy efficiency (Offer et al., 2010).

Possible fuel strategies leading to the commercialization of FCV in China have been discussed also (Wang et al., 2005). First, direct hydrogen fuel cell vehicles will have great difficulties to be introduced as large-scale commercial products in the next decade, mainly due to the required initial capital investment of hydrogen network, and these facilities are too large to be acceptable. For short-term and regional applications, particularly for fuel cell vehicles, fleet demonstration hydrogen FCV still have some viability. Relatively speaking, it is quite feasible using methanol, to promote the development of fuel cell vehicles, however, because the methanol's toxic nature, further studies have to be conducted to ensure their use for safety concern.

In addition to alternative energy supplies, the Government has tended to diversify technology, and to encourage independent innovation. Local governments support for vehicles with different existing energy resources and new types of technology, which fit their own context and hope the central government will ultimately choose among them. While before 2008, no clear message was found from the central government, a reasonable inference is that the Government is waiting for the winner out of this competition.

In April 2009, Chinese officials announced their plan to make China the world's largest producer of electric cars. The Renault-Nissan Alliance will work with China's Ministry of Industry and Information Technology (MITI) to help set up battery recharging networks throughout pilot city, the pilot city is in the country's electrical vehicle pilot program.

According to the latest news of February, 2010, People's Daily, China's government is backing the industry's push toward electric cars. Certain amount of subsidies is considered by the government in order to initiate acceptance of electric vehicle. Beijing has also announced that it will spend \$1.5 billion in grants to help its auto industry innovate.

## 1.2 PROBLEM DEFINITION

There are optimistic opinions can be found on public media, such as, most Chinese car owners don't travel long distances, but rather commute in smoggy, traffic-clogged cities, a switch to plug-in electric vehicles is more plausible in China than in other countries. Another observation is that there might be less resistance from powerful actors in oil industry, since the most powerful and largest stakeholder in China is the central government.

However, uncertainties do not seem to diminish. First, from technological perspective, electric vehicles' range and charging time has always been the target of skepticism. Secondly, infrastructure (such as charging station and grid) in China especially in rural area is far from satisfactory, and income of most family still cannot afford to buy a relatively expensive and not very practical car.

*In view of the present problems, why do the required energy transitions not take place? Why are technological solutions not adopted? What is the role of political factors? And then: how to organize and set in motion the transition?*

Transition involves not only new technologies but also in the user's practice, legislation, policy, infrastructure, networks and institutional change. In short: transition connotes that the combination of technical and social change. Although the transition provides a great potential to achieve environmental benefits, its complexity and uncertainty always confuse decision-makers: which technical issues to stimulate, and how? Traditional technological forecasting methods, however, are not very suited to explore transitions, because they pay virtually no attention to the interaction between technology and society (Elzen, Geels, & Hofman, 2002). For this research I propose a methodology called socio-technical scenarios (STSc), STSc are anticipation tools that can help policy makers develop strategies, considering the transitional nature of the long-term socio-technology change.

The STSc method is based on what we call the *transition theory*. This theory builds upon insights from the domain of *Science and Technology Studies* (STS) that emphasizes the interrelatedness between technical and social change (Elzen, Geels, & Hofman, 2002). STS analyses how technology is shaped by social, economic, cultural and political forces as well as how new technologies shapes society and the interaction between various actors.

### 1.3 RESEARCH QUESTION

To provide insights into possible opportunities and consequences while realizing the potential of electric vehicles in China. The following problems emerge, and they are inevitable in order to answer the question. First, transition theory might possess certain limitation that will prevent it from applying to China's situation without altering? Second, users are important to large scale introduction of EV, both actual users and potential users, their proportion in the whole population, their preference and their symbolic meaning of purchasing EV. Finally, in the socio-technical regime (Geels, 2002) of EV, three analytical dimensions are identified, they are social groups, rules and socio-technical system (related theory would be illustrated in Chapter.2) they have complicated interrelations, and they will formulate the regime of EV in the end. To answer the questions we have with regards to the problems above, I propose the following research questions of this paper.

Main question:

***What are the scenarios for electric vehicles' transition in China?***

Sub-questions:

*Theoretical questions*

- *To what extent do transition theories and methodologies apply to China?*

#### *Empirical questions*

- *Who are the actors that possess significant influence in the transition of electric vehicle in China?*
- *How do actors, interact in the present socio-technical system in China with respect to the case of EV's (and within the case of electric bikes and scooters)?*

#### *Prescriptive questions*

- *What recommendation can be given to China's government on the development of EV based on this study and the socio-technical scenarios developed?*

## 1.4 APPROACH

At the heart of the transition theory are three 'levels' and the interactions between them (the *multi-level* perspective; Kemp, Rip and Schot 2001). These levels are:

1. The *socio-technical landscape*: this describes broad processes and factors in society (e.g. cultural developments, climate policy) that affect a wide range of developments;
2. The *socio-technical regime*: a specific sector of society of interest to the analyst (in our case traffic and transport). Regimes describe the interrelation between technology, policy, user preferences, infrastructures, etc.
3. *Technological niches*: 'alternative' technologies that hold a promise to play a role in the regime but that cannot compete (yet) with existing technologies. This is partly an economic issue but it also requires tuning of a variety of technical and social factors including infrastructure requirements, user preferences, policy, etc. In niches, learning processes and interactions between actors are key.

Innovation within a socio-technical regime is typically incremental. Under specific circumstances, however, development within the socio-technical landscape and/or in niches can get linked to the regime to induce developments that eventually lead to a drastic reform, i.e. a transition.

There are three dimensions (see fig. 1), which form the basic dynamic structure of socio-technical regime, of which the automobile is part—the socio-technical system, actors, and rules that represent institutionalized behavioral patterns (Geels, 2004). This section will examine each of these elements in turn.

ST-system is linkages between elements necessary to fulfill societal functions (e.g. transport, communication, nutrition). As technology is a crucial element in modern societies to fulfill those functions, it makes sense to distinguish the production, distribution and use of technologies as

sub-functions. To fulfill these sub-functions, the necessary elements can be characterized as resources. ST-systems thus consist of artefacts, knowledge, capital, labor, cultural meaning, etc (Geels, 2004).

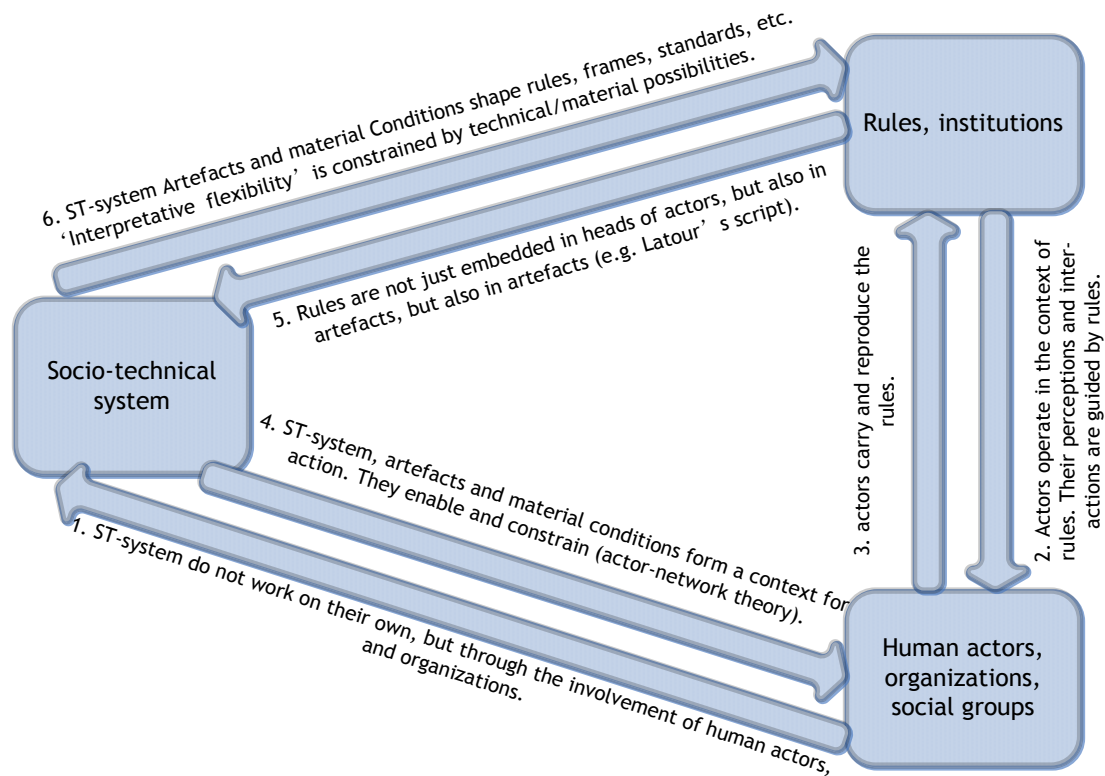


FIGURE 1 THREE INTERRELATED ANALYTIC DIMENSIONS (GEELS, 2004)

Between sub-functions and resources on the one hand, and social groups on the other hand, the relationship between them are dynamic in nature. Actors' interaction (struggle, alliances, exercise power, negotiation, and cooperation within the limits of existing structures and opportunities) at the same time, they take action to adjust these systems. Another important point is that the structure not only constrains but also enables action. Social actors strategically and actively use, interpret and implement the rules of the system. They also creatively reform and rehabilitate them. ST-systems are maintained and changed by activities of the actors, the same time, they formed an action context. Ongoing game and the action of the actor group result in changes of ST system as the impact of actors' move works.

To study socio-technical regime as a whole, the users are not paid enough attention in the previous researches. Sometimes, the user side is taken for granted or narrowed down to a 'selection environment' (Geels, 2004) I would like to suggest that a complete change of mobility systems will only happen, if special attentions are paid to the use of electric vehicles in practice. As long as the driver's behavior and belief are not understood and taken into account, it will always be very difficult for political decision to be implemented and new technical solutions to be widely accepted.

Within the framework multi-level perspective and socio technical scenarios, and in order to shed light to the preference and attitudes of users and potential users of EV in China, an interview will be incorporated in research. EV is new types of automobiles. McCracken (Heffner et al., 2007) notes that qualitative research methods are particularly effective in evaluating new products, since they allow participants to use their own terminology and value frameworks. Second, qualitative interview techniques overcome challenges to examining symbolic meaning and its effect on behavior. McCracken's (Heffner et al., 2007) four-step method of interviewing can be adopted in the research. Steps one and two reveal meanings. And step three tests for expected meanings while providing participants freedom to introduce new ideas. In step four, discrete words or phrases are isolated and then linked with other observations to form themes.

## 1.5 FRAMEWORK FOR THE STUDY

General structure of this study will be categorized in three parts, namely part 1, 2 and 3(see fig. 2), which are designed to answer the three research sub-question proposed in Chapter 1, respectively, the empirical question, the theoretical questions and the prescriptive question. They are not totally sorted chronologically as part 1 and part 2 would have to be carried out concurrently to gain better understanding of the application of the theory and practical facts.

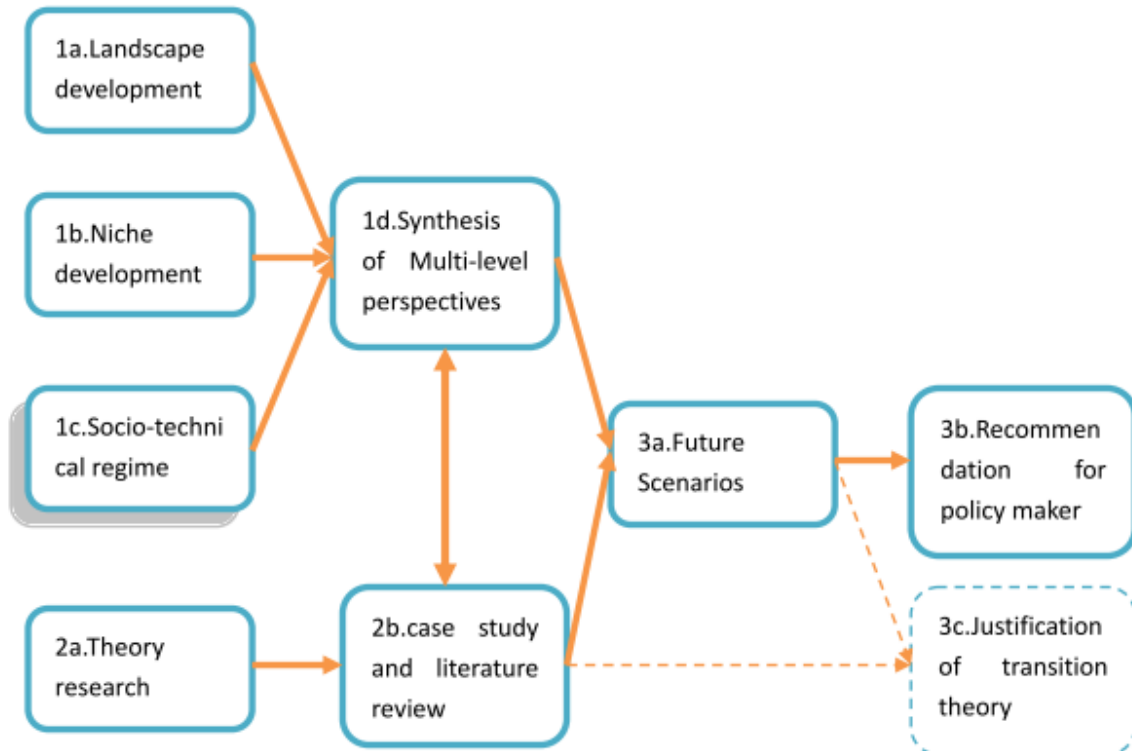
Part1: Based on the model of MLP and step 2 and 3 introduced in previous section, part1 serves to provide insights into the interrelatedness and interactions of the system from micro, meso and macro perspectives. And another aim of this part is to answer the empirical questions: *How do actors, interact in the present socio-technical system in China with respect to the case of EV's (and within the case of electric bikes and scooters)?*

In part 1a and 1b, literature reviewing will be a more appropriate approach. Since individual interviews are quite time and money consuming, and it holds true especially in China considering a relatively high hierarchical distance and bureaucratic manner of work (governmental organizations). Furthermore, individuals hardly represent opinions and orientations of the organizations, instead a systematical and thorough analysis of the published official announcement, news and literatures would provide closer-to-truth information. However, part 1c, does have to incorporate interviews, as explained in Chapter 1, practical use of EV is highlighted in this research, another reason would be its cutting-edge nature, which simply provide no solid feedbacks of potential users in literatures. Thus, the interviews would be designed and conducted under the framework built by McCracken, which has already applied to his study of *symbolic meaning of HEV among California users*, aims to explain how meanings are created, appreciated and communicated by actual users.

Part2: Part 2 is started by part 2a theory research, which is to find basic assumptions of technology dynamics theory and questions it for application in China. In this circumstances, practical case study would provide more insights into the theoretical questions I proposed as, *to what extend do present*



*transition theories and methodologies apply to China?* To answer this questions two kinds of study are chosen for part 2b, a socio-technical scenarios study of the real world case in China of E-bike's large scale introduction, and literatures reviewing in regard of previous work, especially scenarios building of transitions to EV in the western world. The former case study seeks to find possible limitations of application of this method in China and gain knowledge of interaction of transportations regime in China with regard of part 1's target question. The latter reviewing would deal with comparison of the previous work and provide a revised structure for this study.



**FIGURE 2 FRAMEWORK OF THIS STUDY**

Part3: The previous work done in part 1 and 2 will be synthesized and formulate the final research result as the socio-technical scenarios, which would be compared and analyzed to give the recommendation in the end. Another conclusion expected to be drawn from this research is justification of transitions theories' application in China (dotted block in figure). As can be seen in graph, this conclusion is not only based on the scenarios but also the work of part 2b, they together form a more reliable research conclusion.

Topics contributed to the research will be discussed in different chapters, and structure of the report will be presented as following. Chapter 2 will thoroughly describe the chosen theories and methodologies and how they are applied in the previous cases. A justification of applying technology dynamic theories in China will be conducted in Chapter 3 through a case study of E-bike. Chapter 4 is about landscape development, in which emerge driving forces of the socio-technical scenarios. In

Chapter 5, focus will be given to the complex interrelations within the socio-technical regime, which will give us more insight into the context and dynamics of EV field in China. Chapter 5 is about landscape and niche development study, driving force and incumbent seeds emerge. Socio-technical scenarios of electric vehicles' transition will be sketched and elaborate in Chapter 7, it is made based on the result of previous chapters, and differences between scenarios will be compared in this chapter too. Following that In Chapter 8, recommendations will be given as one of the final conclusions, which are presented as answers to the research questions.

## 2 THEORY AND METHODOLOGY

To answer the theoretical question: *'To what extents do transition theories and methodologies apply to China?'* it is important to know what are transition theories and what are included in its methodologies. And to find out its application limitation in the context of China, it is essential to first examine its previous application in the western societies and find what might not be true in the context of China.

In order to answer these questions in this Chapter, I will introduce theoretical background of transition dynamics and methodologies in section 2.1. And in section 2.2, socio-technical scenarios' (STSc) applications in previous electric vehicle research in western societies are examined through a literature review to find out what characteristics these study have presented and their correlation with its application in China.

### 2.1 THEORETICAL BACKGROUND

#### 2.1.1 TRANSITION DYNAMICS

Technological Transitions (TT) describe the way major technological change of social function, such as transport, communications, housing and feeding. Not only technological change is included, but elements, for example, the practice of the user, laws and regulations, industrial networks, infrastructure, and change of symbolism.

From perspective of TT, the analysis is based on a particular technical point of view, resulting from sociology of technology. From this standpoint, technology itself has no power and does nothing. Only with associations such as the personnel agency, social structure and organization then technology carry out its functions. In this context, Hughes (1987) created a 'seamless web', in which physical artifacts, organizations, natural resources, scientific factors, combined heritage artefacts to achieve the functionality. Rip and Kemp (1998) analyze technology as 'configurations that work'. While the term 'configurations' refers to the alignment between a heterogeneous set of elements, the addition 'that work' indicates that the configuration fulfils a function (Geels, 2002). Configurations that work cannot easily be bounded from the rest of society in a simple and obvious way. Practical work is performed routinely, they are part of behaviors pattern of individual or organization. They work only because they are embedded. Societal functions are fulfilled by socio-technical configurations (Geels, 2002).

In this concept, technology transitions include the particular socio-technical configuration changes from one to another, involving the technical alternatives, and other changing factors. This restructuring process will not easily occur, because in a socio-technical configuration the elements are interrelated and mutually consistent. The new technology is difficult to break through, because regulations, infrastructure, user behavior, network integration all have the tendency to maintain the

existing technology. New technologies often face a mismatch with the established socio-institutional framework (Freeman and Perez, 1988). But socio-technical configurations rarely remain 'closed' for good (Geels, 2002). Achieved closure can be withdrawn. The question then becomes how inertia can be understood, and how it is overcome.

In evolutionary economics, there are two views on the process of technological development. In the first view, development is a process of change, selection and retention. In the second view, evolution is a process of unfolding, creating 'new combinations' (Schumpeter, 1934, p. 66), resulting in paths and trajectories. While there are sophisticated debates in evolutionary economics about 'variation' (e.g. learning within firms, organizational routines, knowledge management), 'selection' is taken somewhat for granted. Markets are simply assumed to be 'out there'. The completely new technology, however, has no established market, and no fixed preferences. The new technology, market and user preferences co-develop with each other.

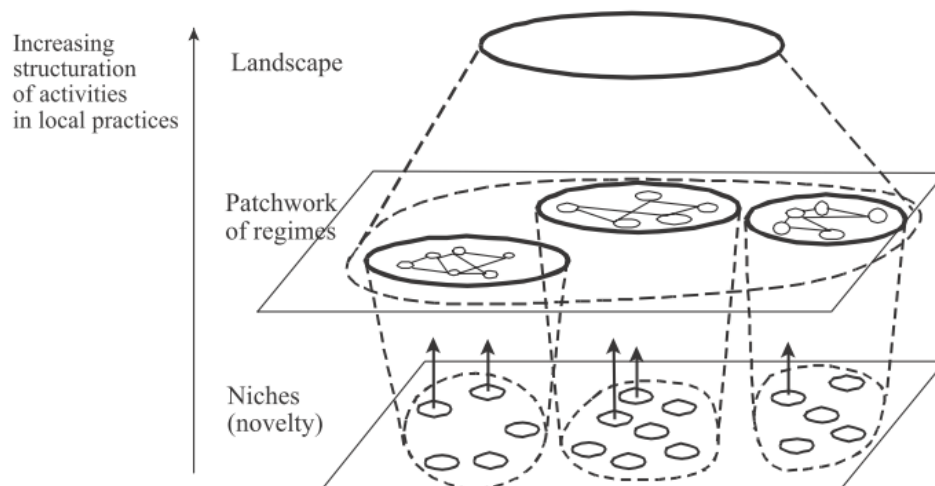
Furthermore, selection is more than adoption. Users also have to integrate new technologies in their practices, organizations and routines, something which involves learning, adjustments and 'domestication' (Lie and Sørensen, 1996). Another criticism is from that of the selection environment which has a wider range of user market. Policies and institutions also played a role, and infrastructure, cultural discourse or maintenance of the network. Although Nelson (1994, 1995) has done some work on such wider co-evolution processes, the topic is under-exposed in evolutionary economics. With regard to evolutionary economics (Nelson, Winter, 1982), Geels (2002) explores two new things. First, a multi-level perspective is described to combine both views of evolution. Second, he complements the focus on 'variations' with attention for the wider selection environment, using the concept of socio-technical configurations. In technology studies, the idea that linkages between technical and social elements provide stability is particularly emphasized in actor-network theory (e.g. Latour, 1991, 1993; Law and Callon, 1992). A socio-technical change is depicted as transfer of organization and substitution, an element reweaving assembly process. In a network, element changes can trigger changes in other elements. Experience of this process shows that there is usually a micro-focus. There appears to be little attention around on long-term, large-scale science and technology developments. Multi-level perspective (MLP) model serves to address this gap.

### 2.1.2 MULTI-LEVEL PERSPECTIVES

At the heart of the transition theory are three 'levels' (see Fig. 3) and the interactions between them (see Fig. 4) (the multi-level perspective; Kemp, Rip and Schot 2001). MLP practically use the perspective of evolutionary economics, sociology, technology, history, and technology and innovation research. MLP is divided into three levels of analysis and heuristic understanding of system innovation.

The meso-level is formed by socio-technical regimes. This concept builds upon the concept of technological regimes (Nelson, Winter, 1982), but is wider in two respects. First, while Nelson and

Winter refer to cognitive routines, Rip and Kemp widen the regime concept with the sociological category of rules: technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures (Rip, Kemp, 1998). While the cognitive routines of Nelson and Winter are embedded in the minds of engineers, these rules are embedded more widely in the knowledge base, engineering practices, corporate governance structures, manufacturing processes and product characteristics. Second, socio-technical regimes not only refer to the social group of engineers and firms, but also to other social groups (Geels, 2005). Socio-technical system is actively created and maintained by several social groups. They reproduce elements from their activities and the links between socio-technical systems. As these social groups have their own distinct characteristics and environment of their choice, they have relative autonomy. On the other hand, the groups are also interdependent and influencing each other. Interdependence and linkages between subsystems occurs, because the coordination of consistent activities of social groups. This system represents the concept of social technology.



**FIGURE 3 MULTIPLE LEVELS AS A NESTED HIERARCHY (GEELS, 2002).**

By providing direction and coordination activities of the groups of actors, socio-technical regime is dependent on the stability of socio-technical systems. This stability is dynamic, which means that innovation, but still there is a progressive nature, leading technology trajectory and path dependence.

Technical niche formed the Micro-level by the radical innovations (variation). As the performance of the initial novelties is low, they appear in protected spaces against the mainstream market from selection. Niches thus act as incubation rooms for radical novelties (Schot, 1998). Niche is important because they provide the location of the learning process (Geels, 2005). Learning process occurs at many domains, such as technology, user preferences, regulation, symbolic meaning, infrastructure and production systems. Niches also provide space for the establishment of social networks and

support innovation, for example, supply chain, user and producer relations. These internal niche processes have been analyzed and described under the heading of strategic niche management (Geels, 2005)

The macro level is formed by socio-technical landscape, which means the wider external environment that affect social development (for example, globalization, environmental issues, cultural changes). This analogy is that the relative hardness of the context and the content of the material and their integration into society, such as the city's physical and spatial arrangements, roads, electricity and other infrastructure. Landscape is beyond the direct influence of actors, and cannot be changed at will.

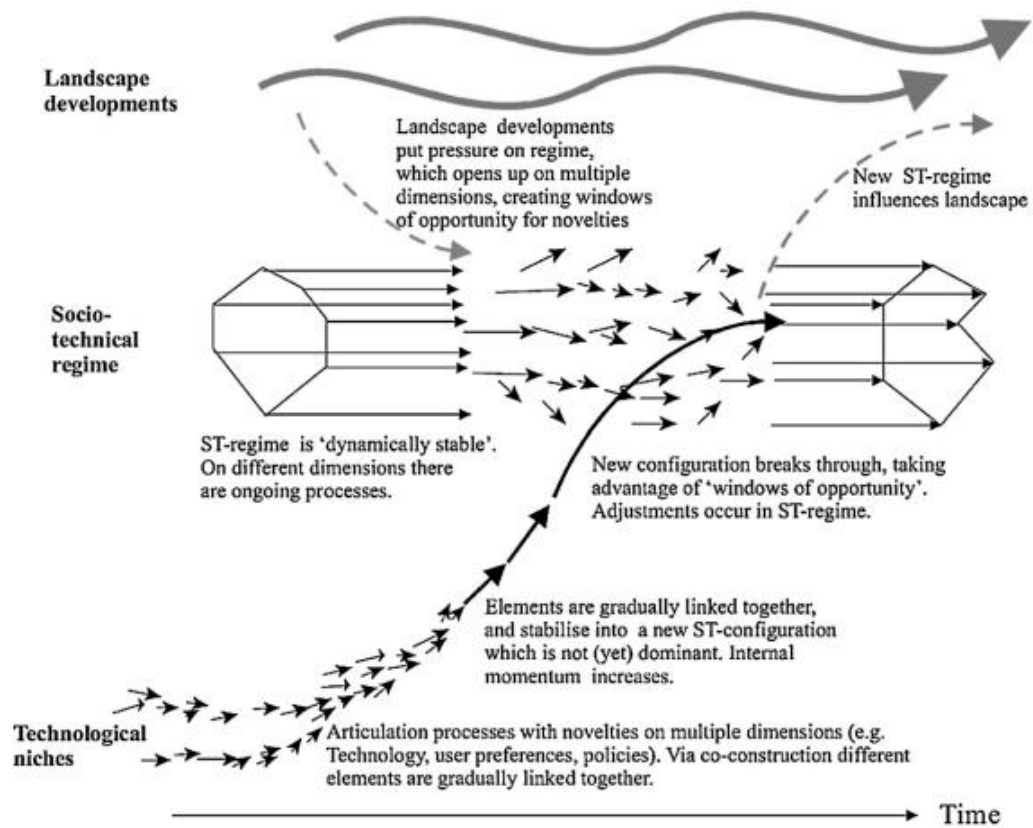


FIGURE 4 A DYNAMIC MULTI-LEVEL PERSPECTIVE ON SYSTEM INNOVATIONS (GEELS, 2005)

The (socio) logic of three levels is that they provide co-ordination of activities and local practices in different structures. The relationship between three concepts can be understood as a nested hierarchy, that is, the regimes are within the landscape and niches are embedded regimes (see Figure. 1). The work of niche is often regime-oriented (and therefore, arrows in the figure). Actors support the new niche and hope eventually it will come into practice, or even replace existing regime. It is not easy, but because the current system is entrenched in many respects (for example, from institutional, organizational, economic, cultural). Radical novelties lack of coordination and tend to conflict with the

existing system, which is not easily broken through. However, the niche is a key institutional innovation, as they provide the seeds of change.

The key point is that, system innovations come from the multi-level dynamic interaction between each other. Several phases can be distinguished in transitions (Rotmans, Kemp, & Van Asselt, 2001). In the first phase, novelties emerge in niches in the context of existing regime and landscape developments. There is not yet a dominant design, and there may be various technical forms competing with each other. Actors improvise, engage in experiments to work out the best design and find out what users want.

In the second phase the novelty is used in small market niches, which provide resources for technical specialization. Gradually, a dedicated community of engineers and producers emerges, collectively directing their activities to the improvement of the new technology. Engineers gradually develop new rules, and the new technology develops a technical trajectory of its own. The new technology gradually improves, as a result of learning processes. As users interact with the new technology and incorporate them into their user practices, they gradually explore new functionalities. This second phase results in a stabilization of rules, e.g., a dominant design, articulation of user preferences.

The third phase is characterized by a breakthrough of the new technology, wide diffusion and competition with the established regime. On the one hand, there are internal drivers for breakthrough, e.g., price/performance improvements, increasing returns to adoption, and actors with interests that push for further expansion of the technology. On the other hand, breakthrough depends on external circumstances and windows of opportunity (see Fig. 4). The regime may come under pressure from changes at the landscape level or there may be internal technical problems in the regime, which cannot be met with the available technology. There may also be negative externalities in the regime, changing user preferences or stricter regulations, which create problems for the existing technology. The key point of the MLP is that system innovations occur as the outcome of linkages between developments at multiple levels. As the new technology enters mainstream markets, it enters a competitive relationship with the established regime.

In the fourth phase the new technology replaces the old regime, which is accompanied by changes on wider dimensions of the socio-technical regime. This often happens in a gradual fashion, because the creation of a new socio-technical regime takes time. Furthermore, incumbents tend to stick to old technologies, because of vested interests and sunk investments.

The new regime could ultimately affect the development of the wider landscape. MLP is an important aspect of institutional innovation instead of simple causal relationship. There is no simple cause or driver. On the contrary, there are interactions between variety of dimensions and levels of process at the same time. System innovations occur when these elements connect in the processes and reinforce each other (circular causality).

## 2.2 METHODOLOGY AND APPLICATION

### 2.2.1 SOCIO-TECHNICAL SCENARIOS

Transition involves not only new technologies but also in the user's practice, legislation, policy, infrastructure, networks and institutional change. In short: transition connotes that the combination of technical and social change. Although the transition provides a great potential to achieve environmental benefits, its complexity and uncertainty always confuse decision-makers: which technical issues to stimulate, and how? To help them, they need anticipation tools with that. Traditional technological forecasting methods, however, are not very suited to explore transitions, because they pay virtually no attention to the interaction between technology and society (Elzen, Geels, & Hofman, 2002). To remedy this shortfall, this section introduces a tool: socio-technical scenarios (STSc). STSc are anticipation tools that can help policy makers develop strategies, considering the transitional nature of the long-term socio-technology change.

In this regard, I will introduce a method that takes into account the four directions to improve. This is the so-called socio-technical program (STSc), to explore possible routes for the transition. In order to understand and describe the technical transition Geels and Elzen use a theory of social technology changes, it is robust and broad enough to cope with a variety of situations. Therefore, the STSc is theory-based.

A STSc is a story that describes possible future developments, making use of the patterns and mechanisms<sup>ii</sup> (Elzen, Geels, & Hofman, 2002). The story is in terms of complexity and reconfiguration processes, and to show the multi-level perspective in action, sometime it is written with a mosaic style of shifting between different elements of the socio-technical regime (Geels, 2002). In principle, everything is possible in a STSc but the developments described have to be plausible in terms of the multi-level theory and the patterns and mechanisms used should be likely to emerge under the given circumstances. Thus a STSc-method can lead to a wide variety of different outcomes, but, more importantly, since the developments have to match the multi-level theory it allows to explore why developments lead to certain outcomes. Thus, the method can also be a stepping stone to inform strategies that attempt to realise specific outcomes that are desired.

#### 2.2.1.1 DYNAMIC OF SOCIO-TECHNICAL CHANGE

The STSc method is based on what we call the transition theory. This theory is based on scientific and technological studies (STS), which emphasis on technology and the linkages between social changes. STS engages in how technology is formed by the social, economic, cultural and political forces, and how new technologies reform society and social interaction between various actors in analysis.

At the heart of the transition theory are three 'levels' and the interactions between them (the multi-level perspective; Kemp, Rip and Schot 2001). These levels are (Elzen, Geels, & Hofman, 2002):



1. The socio-technical landscape: this describes broad processes and factors in society (e.g. cultural developments, climate policy) that affect a wide range of developments;
2. The socio-technical regime: a specific sector of society of interest to the analyst (in our case traffic and transport). Regimes describe the interrelation between technology, policy, user preferences, infrastructures, etc.
3. Technological niches: ‘alternative’ technologies that hold a promise to play a role in the regime but that cannot compete (yet) with existing technologies. This is partly an economic issue but it also requires tuning of a variety of technical and social factors including infrastructure requirements, user preferences, policy, etc. In niches, learning processes and interactions between actors are key.

Innovation within a socio-technical regime is typically incremental. Under specific circumstances, however, development within the socio-technical landscape and/or in niches can get linked to the regime to induce developments that eventually lead to a drastic reform, i.e. a transition.

#### 2.2.1.2 THREE ANALYTICAL DIMENSIONS OF SOCIO-TECHNICAL REGIME

There are three dimensions (see fig. 1), which form the basic dynamic structure of socio-technical regime, of which the automobile is part—the socio-technical system, actors, and rules that represent institutionalized behavioral patterns (Geels, 2004). This section will examine each of these elements in turn.

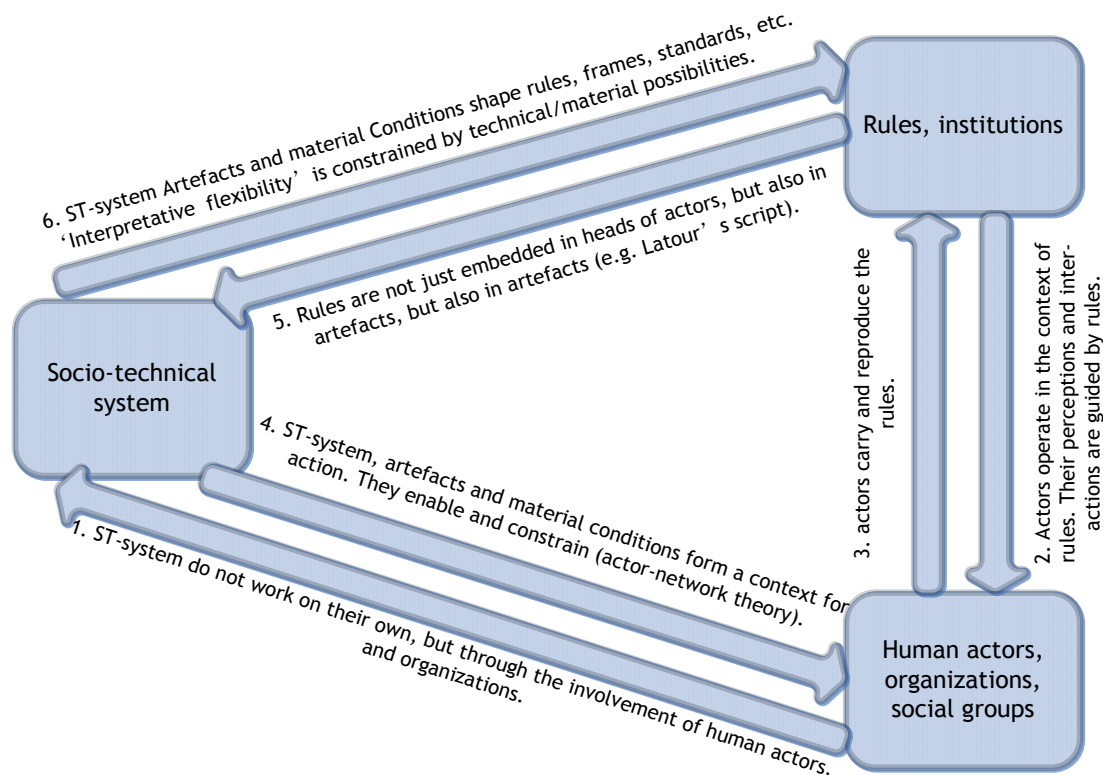


Figure 1 Three interrelated analytic dimensions (Geels, 2004)

ST-system is linkages between elements necessary to fulfill societal functions (e.g. transport, communication, nutrition). As technology is a crucial element in modern societies to fulfill those functions, it makes sense to distinguish the production, distribution and use of technologies as sub-functions. To fulfill these sub-functions, the necessary elements can be characterized as resources. ST-systems thus consist of artefacts, knowledge, capital, labor, cultural meaning, etc (Geels, 2004).

Between sub-functions and resources on the one hand, and social groups on the other hand, the relationship between them are dynamic in nature. Actors' interaction (struggle, alliances, exercise power, negotiation, and cooperation within the limits of existing structures and opportunities) at the same time, they take action to adjust these systems. Another important point is that the structure not only constrains but also enables action. Social actors strategically and actively use, interpret and implement the rules of the system. They also creatively reform and rehabilitate them.

ST-systems are maintained and changed by activities of the actors, the same time, they formed an action context. Ongoing game and the action of the actor group result in changes of ST system as the impact of actors' move works.

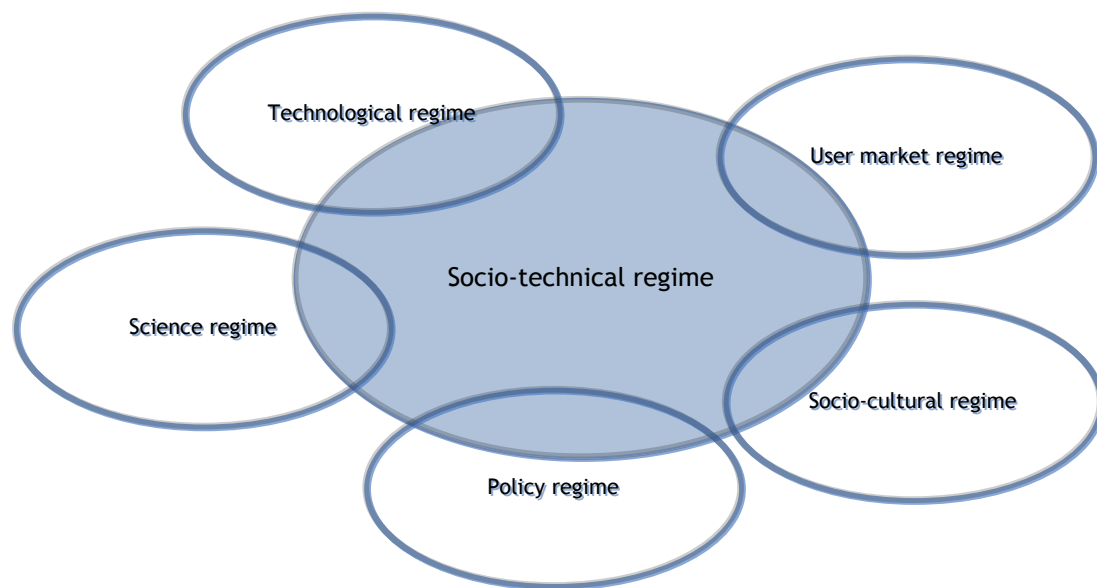
Rules are not just linked within regimes, but also between regimes. ST-regimes can be understood as the 'deep-structure' or grammar of ST-systems, and are carried by the social groups. ST-regimes do not encompass the entirety of other regimes, but only refer to those rules, which are aligned to each other (Geels, 2004). It indicates that different regimes have relative autonomy on the one hand, but are interdependent on the other hand (see fig. 5).

Between the three dimensions, there are six kinds of interaction identified by Geels (2002), as shown in Fig. 1.

1. Actors reproduce the elements and linkages in ST-systems in their activities.
2. To counter these tendencies attention also needs to be paid to existing rules, regimes and institutions which provide constraining and enabling contexts for actors (individual human beings, organizations, groups). Perceptions and (inter)actions of actors and organizations are guided by these rules.
3. On the other hand, actors carry and (re)produce the rules in their activities.
4. While this 'duality of structure' has been well conceptualized in sociology, this discipline almost entirely neglects the material nature of modern societies. Technology studies, in particular actor-network theory, have criticized traditional sociology on this point. Human beings in modern societies do not live in a biotope, but in a technotope. We are surrounded by technologies and material contexts, ranging from buildings, roads, elevators, appliances, etc. These technologies are not only neutral instruments, but also shape our perceptions, behavioral patterns and activities. Socio-technical systems thus form a structuring context for human action. The difference between

baboons and human beings is not just that the latter have more rules which structure social interactions, but also that they interact in a huge technical context (Strum and Latour, 1999).

5. Another insight from technology studies is that rules are not just shared in social groups and carried inside actors' heads, but can also be embedded in artefacts and practices. Actor-network theorists such Akrich (1992) and Latour (1992) introduced the notion of the 'script' of an artefact to capture how technological objects enable or constrain human relations as well as relationships between people and things. 'Like a film script, technical objects define a framework of action together with the actors and space in which they are supposed to act' (Akrich, 1992, p. 208).



**FIGURE 5 META-COORDINATION THROUGH SOCIO-TECHNICAL REGIMES**

6. Technologies have a certain 'hardness' or obduracy, which has to do with their material nature, but also with economic aspects (e.g. sunk costs). Because of this hardness, technologies and material arrangements may be harder to change than rules or laws. They may even give social relationships more durability (Latour, 1991). This hardness also implies that artefacts cannot entirely be shaped at will. Technical possibilities and scientific laws constrain the degree to which interpretations can be made.

This structure is not only dynamic, but provides a mechanism to stabilize within itself. First, rules and regimes provide stability by guiding perceptions and actions. There are three kinds of rules, regulative, normative and cognitive rules. *Regulative rules* dimension refers to explicit, formal rules, which constrain behavior and regulate interactions, e.g. laws, government system, protocols, standards, etc, which is legally sanctioned. *Normative rules* confer values, norms, role expectations, codes of conduct, which is morally governed. *Cognitive rules* constitute the nature of reality and the frames through which meaning or sense is made and can be problem agendas, beliefs, bodies of knowledge, jargon/language, most people tend to take this kinds of rules for granted, which is culturally

supported and conceptually correct. Second, the actors and organizations are embedded in interdependent networks and mutual dependencies which consolidate stability. Third, the socio-technical systems, particularly artefacts and physical networks, there is a certain 'hardness', which makes them difficult to change.

### 2.2.1.3 QUASI-EVOLUTIONARY MODEL OF SOCIO-TECHNICAL TRANSITIONS

Most innovation takes place within the regime, typically leading to gradual evolution or regime optimization (Elzen, Geels, & Hofman, 2002). This gradual pattern comes about from a wide range of elements, including technical, behavioral, cultural, political, that are mutually related and, therefore, cannot be easily changed. If a new opportunity arises, usually part of the system to deal with this threat. Smith (2005) suggests that regime transformation processes can be organized according to whether they contribute to the articulation of selection pressures (exerting pressure for change), or whether they contribute to the adaptive capacity (resourcing and coordinating a response to this pressure).

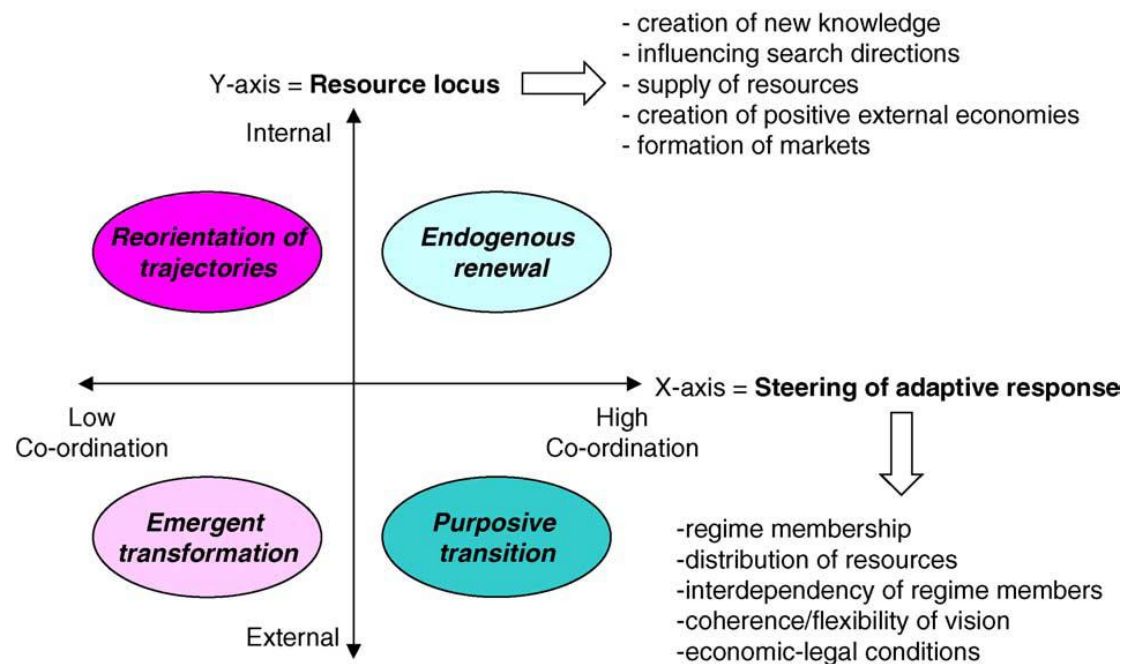


FIGURE 6 TRANSITION CONTEXTS AS A FUNCTION OF DEGREE OF COORDINATION TO SELECTION PRESSURES AND THE LOCUS OF ADAPTIVE RESOURCES (SMITH ET AL., 2005).

A quasi-evolutionary model (see Fig. 6) of socio-technical transitions proposed by Smith (2005) is described in which regimes face selection pressures continuously. Differentiated transition contexts determine the form and direction of regime change in response to these pressures. Analysis at the level of the socio-technical regime, on the other hand, includes such factors, but goes beyond them to consider less economically visible pressures emanating from institutional structures and conventions, including changes in broad political economic 'landscapes', or wider socio-cultural attitudes and

trends (Geels, 2004). Other pressures come from the social change, not for any particular regime, but it can bring the regime of selection pressure.

All regimes have some capacity and resources to respond to the selection pressures bearing on them. We refer to this feature as the *adaptive capacity* of a regime, and the better that regime members are able to fulfill these regime functions, the better then regime as a whole will be able to respond to selection pressures (Smith et al., 2005). The more intensive the threat of such pressure, the greater resources devote into the defense of certain regime, through the adjustment and adaptation.

The different contexts for transition can be mapped using the two dimensions of change. The first dimension measures whether change is envisaged and actively coordinated, either at the level of the regime membership, or on the part of some higher level governance process, in response to prevailing selection pressures, or whether it is the emergent outcome of the co-evolutionary behaviour of regime members (involving no new steering mechanisms) (Smith et al., 2005). The second dimension relates to the extent the response to selection pressures within regime is based on the existing resources (or can adopted by the regime), or in function, they can only rely on resources outside the existing regime. The trajectory of the innovation and adaptation is important to the nature of the transformation process.

#### ENDOGENOUS RENEWAL (COORDINATED RESPONSE, INTERNAL ADAPTATION)

Endogenous renewal arises in the context of regime members (firms, supply chains, customers and regulators) making conscious efforts to find ways of responding to perceived competitive threats to a regime. Decisions over future technological choices will be guided by past experience. Thus, the transformation process will tend to be incremental and path following (Smith et al., 2005).

#### RE-ORIENTATION OF TRAJECTORIES (UNCOORDINATED RESPONSE, INTERNAL ADAPTATION)

In these regimes, the trajectory can be fundamentally changed by the internal processes, which are not related to discrete actors, networks and systems of the regime. Stimulus for Such radical re-orientation is experienced as a shock, may be internal or external to the regime. This radical transformation in the technical and operational characteristics of generation systems was not widely anticipated or intended, but arose through the conjunction of a series of uncoordinated technological opportunities, changes in market regulation, the availability of new and cheaper gas supplies, and obstacles facing alternatives, such as coal and nuclear generation (Smith et al., 2005).

#### EMERGENT TRANSFORMATION (UNCOORDINATED RESPONSE, EXTERNAL ADAPTATION)

This type of transformation arises from uncoordinated pressures for change and responses based on resources and capabilities lying outside the incumbent regime (Smith et al., 2005). The origin of this type of transformation is often in scientific activity, typically carried out in universities or small firms operating outside existing industries (Dosi, 1988). In the absence of a clear definition and coordination of the transition cover the specific endpoint, increased uncertainty of appropriate governance measures.

### PURPOSIVE TRANSITIONS (COORDINATED RESPONSE, EXTERNAL ADAPTATION)

Although the emergent transition possesses a quality of autonomy, they can be distinguished from the transition, which also use of external resources and is deliberately pursued, from the beginning to reflect the community's expectations and interests. Key to the transition management project is the greater role afforded to external social actors, both in articulating pressure for change, and in providing the resources, capabilities and networks that condition the responses (Smith et al., 2005). Transition management is also a deliberate attempt to change the regime under the guidance of the consensus vision (so the selection pressure is highly articulated).

#### 2.2.1.4 STEPS

Elzen et al. (2002) have developed seven consecutive steps to make a socio-technical scenario:

##### 1. Design choices and contours of the scenarios:

In this first step the purpose of the scenarios has to be made explicit, together with some design choices, such as the number of scenarios to be developed and the time frame chosen. In this stage one should also provide some general characteristics of the regime and indicate some promising niches.

##### 2. Inventory of potential linkages as promising transition elements:

The second step consists of establishing what is called 'transition elements', possible linkages of elements at the three levels that could create innovations and form the bases for a transition. Transition elements can be present in many different dimensions, such as technical, policy, cultural, societal, environmental, financial, as well as dimensions concerning market, production and infrastructure. The linkage opportunities described here can be used when building the scenarios.

##### 3. Analysis of dynamic at regime, landscape and niche level:

- Regime

According to the transition theory, it is the alignment in developments at the three levels that enables a shift in the existing regime to happen. When niche developments together with landscape factors put pressure on the existing regime, 'windows of opportunity' may open up, increasing like this the chance for radical innovations to break through. Therefore, a transition processes demands the analysis of the existing system as well as the understanding of how this system has been created in the recent past. This step thus tries to identify major characteristics and trends in the regime, including main actors, patterns and possible tensions that could provide linkages to niche developments.

- Landscape

Landscape factors may influence the dynamics at the regime and niche levels, as well as the possible interactions between them. That's why the goal of this step is to identify significant landscape features such as geo-political dimensions, related policies, societal and cultural factors, as well as economic and environmental issues.

- Niche

The objective here is to further describe the niches identified in steps 1 and 2, including the recent dynamics, current status and future potentials. It should include alternative technological forms, the possible markets, a brief history of the niche, the main actors, costs, barriers, user preferences, policies, regulations, and so on.

#### 4. Develop scenario skeletons:

In this step a brief version of the scenario will be made. For that purpose, the links between the crucial elements of landscape, regime and niche will be combined to form initial paths. This will include the niches that will break through, together with the related time-path and the reasons behind such developments. Relevant cross-linking of niches and expected market share should also be incorporated. Usually this step begins by defining the general shape of the regime at the end of the scenario timeframe, followed by a sketch of the development pathways for each of the technologies being dealt with. It is recommended to distinguish the paths for the regime level under the four transition phases (pre-development, take-off, breakthrough, and stabilization). After that, a consistency check should be done to control if the assumptions are coherent with each other.

#### 5. Make the scenario:

At this point the scenario skeleton will be further elaborated in a much more detailed level. Special attention is required to make sure the linkages made are coherent with the multi-level perspective.

#### 6. Reflect on the scenarios:

This is the step when the constructed scenarios will have to be compared to each other, aiming to reveal main differences and similarities. Special aspects to look at are regime characteristics at the end of the timeframe, the different pathways from the present towards the scenarios designed, and the main driving forces that resulted in the transition.

#### 7. Develop policy recommendations:

This final stage starts by briefly mapping current policies, in order to understand where potential changes can be suggested to foster the expected transition. After this initial analysis, recommendations are made to modify, merge or create supportive policies. Suggestions for using different policy strategies under certain circumstances or to stimulate a special kind of learning can also be done.

## 2.2.2 LITERATURE REVIEW OF TRANSITION DYNAMIC THEORIES' APPLICATION ON EV

This section aims to provide more insights of applying transition dynamic theories to China through two approaches. By reviewing previous work based on transitions theory and multi-level perspective focusing on western society to identify similarities and differences between these societies and China, which might result in diverse research outcome. In first part, some framework for the research and assumptions of contributing actors in the analysis are presented and discussed. In the second part, their scenarios are compared and so are the driving forces and tipping points different researchers have identified in order to find a better way to formulate my own scenarios in this study.

### 2.2.2.1 REGIME DEVELOPMENT

Many attempts have been made to implement the multi-level perspective model to real world cases, among them some conceptual simulation model have been formulated. System dynamic is often the chosen approach to interpret. As shown in figure 1 by *J. Köhler* (2009). This model provides a point of view of how MLP work as a practical model instead of abstract concepts of interacting levels.

The overall structure of the model is shown in fig. 7. Unlike most agent-based model, this model has a hierarchical structure. The model includes the regime and the niche as agents, with a niche's concept extends to the empowered niche agent (ENA). Only one regime is allowed to in power at one time, although the system may at times has no regime at all. There may be zero, one or a few niches and ENAs. We define the type of agent by their different levels of strength. The regime is defined by the strongest agent of system and tends to dominate the rest, niche has much reduced strength.

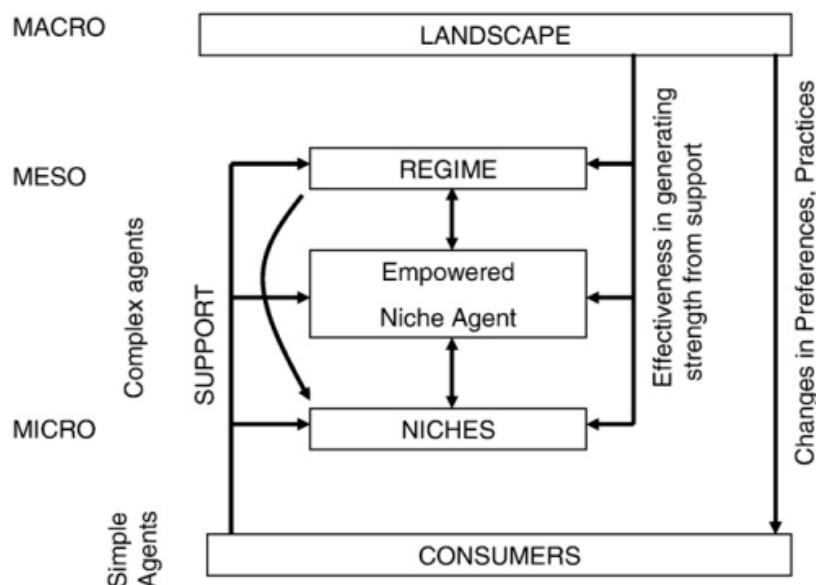


FIGURE 7 OVERALL STRUCTURE OF THE SD MODEL (KÖHLER ET AL., 2009)

And some other framework of transitions model is suggested by Struben and Sterman (2007) that the transition to the current ICE-dominated system in the late 19<sup>th</sup> century can provides insights into the challenges of creating an alternative transportation system. They argued that word of mouth and



related network effects played an important role in the rise of ICE, and the larger the installed base of a platform, the greater the exposure to and knowledge of that platform among potential adopters, increasing the chances that they will consider and choose that platform (Jeroen, Struben, & Sterman, 2007) However, besides similarities one can sure see in these two cases, there could also be crucial elements that are different in these two transitions can result in huge difference in the outcomes. For example, transition from conventional vehicle to electric vehicle is not as evolutionary as in the previous case, there is no absolute advantage in mobility improvement, which resulted in the difference in their driving force. That one is market-driven, while the other is possible from landscape pressure or competent market niche.

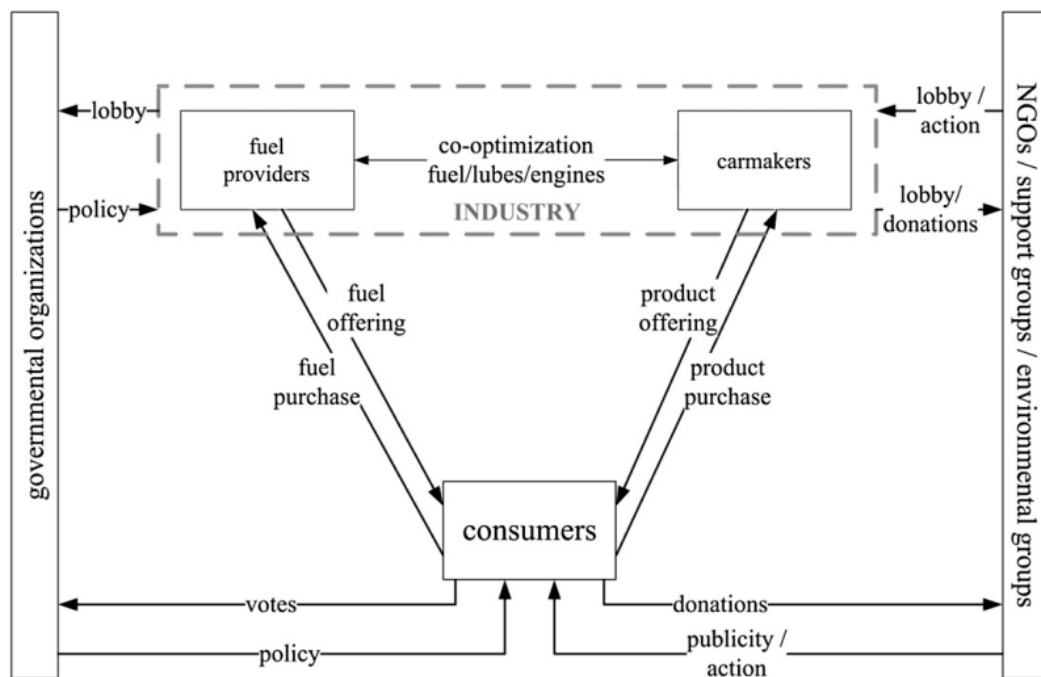


FIGURE 8 ACTORS IN THE SOCIO-TECHNICAL REGIME OF CAR-BASED TRANSPORTATION (VAN BREE ET AL., 2010)

### ACTOR

A framework of actors involved is proposed by B. van Bree (2010) (see fig. 8). As he identified fuel providers, car manufacturers, and consumers are central to the system. The other groups (governments and non-governmental organizations, NGOs) attempt to influence the system. And following that he conducted the analysis of the carmaker–consumer relationship, and he argues this helps to provide a more complete picture of a possible transition. Although this relationship will likely play an important role in a transition, its exact role is still quite uncertain (van Bree, et al., 2010). This actor analysis might be a well founded illustration of situation of the Netherlands. However, it is far from correct while applying to China. Since governments as important actors is involved and expected to be a potentially active role in this transition, difference of political structure would have to be taken into account. This new actor analysis will be carried out in Chapter 4. Although, major changes are expected in the following research, consumer-carmaker relationship is a well taken point that

worth further analysis. And actors presented in this diagram will also be potentially crucial in actor analysis for China's situation.

## CONSUMER

Hauser (1993) noted that consumers' choice among platforms depends on their consideration set, and, within that set, the relative attractiveness of each. Consumers start to think about an alternative only when they have sufficiently exposed to it. A consumer's willingness to consider a vehicle type increases through direct exposure to the different platforms, marketing, media attention and word-of-mouth, and the attractiveness of each platform in the consideration set is a function of attributes including price, operating cost, performance, driving range, fuel and service availability, and ecological impact (Jeroen, Struben, Sterman, 2007). Attractiveness for each platform accumulates through improvement of performance, cost, range, etc, which is done through learning by doing, R&D and scale economies, among which R&D and learning by doing directly lead to improvement for individual platform, however, they might spill over to the others. Complementary assets such as service, parts, maintenance, and fuel distribution infrastructure critically influence a platform's attractiveness (Jeroen, Struben, Sterman, 2007).

Interviews of actual users of HEV have been conducted by R.R. Heffner (2007). HEV adopters interviewed in this study bought meanings of themselves, which they then used in construction of narratives of self identity. Data were collected in ethnographic interviews with hybrid electric vehicle owners in the California, and analyzed using methods based on semiotic theory (Heffner et al., 2007). In particular, the study was to investigate how widely recognized social meaning (denotation) is connecting to more of personal meaning (connotation) and the effects the two kinds of meaning have on the vehicle purchase and use. The following is a summary of the results from this study:

- a) Preserve the environment: Many households acknowledged purchasing their HEVs as a response to environmental concerns. However, most had only a basic understanding of environmental issues or the ecological benefits of HEVs.
- b) Oppose war: All of the denotations ascribed to HEVs by households in this sample are historically as well as culturally situated. Of the denotations discussed here, opposition to war likely depends most on recent events for its meaning and importance.
- c) Manage personal finances: Whether HEVs save their owners money has been widely discussed in the popular press. HEV owners linked their vehicles to three underlying connotations: maturity/sensibility, ethics, and intelligence/awareness.
- d) Reduce support for oil producers: HEVs also symbolize reducing support for oil producers: multinational energy companies and the governments of oil-producing nations, including Middle Eastern oil-producers.
- e) Embrace new technology: Finally, many owners were motivated by their perception that HEVs are new, advanced technology vehicles. However, few owners had more than a basic understanding of the hybrid-electric powertrain.

Obviously, the results showing mainly reflect meaning and connotations of HEV in California. However, this approach can be adopted and applied to China, and results can be compared. Although HEV or EV users are hard to find in China, since many models are simply not for sale there. Opinions of some potential auto purchaser and user can be collected and analyzed.

#### CARMAKER

In each regime, a variety of technical solutions have been developed to address various issues. These innovations can be the future regime in two distinct roles: they can help the existing regime to become sustainable to help it overcome the internal problems, to meet the continued growth and response to external pressures, or, contribute to the formation of a kind of transformation of the existing regime. In this section, I will describe innovation of the individual car-based regime.

In the individual car-based transport regime, the following four types of technological innovations are pursued by car makers in accordance with their own interests, capabilities and expectations (Kemp, Simon, 1999).

**ENVIRONMENTALLY IMPROVED ICE VEHICLES** There are many ways to improve ICEVs. The following three types of technical solutions receive most attention of all: fuel-efficient engines (direct injection engines for instance), end of pipe devices (catalysts such as NOx catalysts) and new car design (less drag and weight).

**ALTERNATIVE FUEL VEHICLES** Alternative fuel vehicles (AFVs) are the second option. Among them, the liquefied petroleum gas (LPG) and compressed natural gas (CNG) is considered the most promising alternative fuel and reduced CO emissions from 80 to 90% of, HC emissions from 70 to 80% percent, carbon dioxide emissions by 14% for LPG vehicles. They give priority to high mileage vehicles, commercial fleets, the low-fuel cost is in compensation of the high cost engines and fuel storage costs, which is a major obstacle today to their wide application.

**ELECTRIC DRIVE TECHNOLOGIES, COMPRISING BATTERY-POWERED ELECTRIC VEHICLES (BEVs), HYBRID ELECTRIC VEHICLES (HEVs) AND FUEL CELL VEHICLES (FCVs)** Hybrid cars are considered from a user, the most attractive option. It provides a combination of the ICE (gasoline or diesel engines, gas turbine ...) with electric motor to offset the limited range of BEV, there are two different design configurations: parallel hybrid and serial hybrid. In the former case, the electric motor is used for urban drive and ICE ensure a sufficient range of 500 kilometers and matching speed of driving a car. In the series combination of the ICE as a generator function to promote the electric motor to drive the wheels; electric energy is also received from a battery, that is recharged by the generator.

**ADVANCED TRANSPORT TELEMATICS SYSTEMS** Telematics applications in the provision of travel information, drivers, transport companies, users and traffic management for traffic may help to improve road safety and traffic flow while reducing energy consumption related to congestion. To the

transport technology can be divided into three main categories: traffic management systems, static and dynamic route guidance systems and advanced driver support.

#### CONSUMER-CARMAKER RELATIONSHIP

The exchange between consumers and car manufacturers exhibits typical behavioral patterns—it has been institutionalized, and these patterns can be related to formal, normative, and cognitive rules [21]. The following sections describe four patterns of behavior in the carmaker–consumer relationship identified by B. van Bree (2010). Perceptions, attitudes, and expectations play an important role in this relationship and hence most patterns are based on cognitive rules.

a) Purchasing process

The number and variety of automobile models available is overwhelming. Consumers are unable to make a detailed assessment of all models. The purchasing process can be characterized as a cognitive rule that describes how the car market works—it reflects how user preferences play a role in the carmaker–consumer relationship.

b) Variety

Assuming that consumer perception of innovations such as FCVs and BEVs is comparable to that of HEVs, an ongoing trend complicates their introduction. The competition between car manufacturers that drives the increase in variety can be regarded as a normative rule in the car market, since it follows from the goals carmakers set for themselves (e.g. revenue growth). The various motivations for car use that enable the extensive variety represent symbolic meanings of technology and hence a cognitive rule.

c) Modularity

Car manufacturers have obviously acknowledged that expanding their product lines—while profitable—is at odds with the foundations of their production system. Underlying increasing modularity is the conviction that outsourcing reduces costs. This conviction represents a cognitive rule.

d) Upgrading

Consumer expectations and competition between car manufacturers drive incremental improvements. Cars get better on a number of attributes. Incremental improvements of cars are enabled by consumer expectations and car manufacturers' drive to increase profitability. It can therefore be categorized as a cognitive rule.

#### 2.2.2.2 SCENARIOS

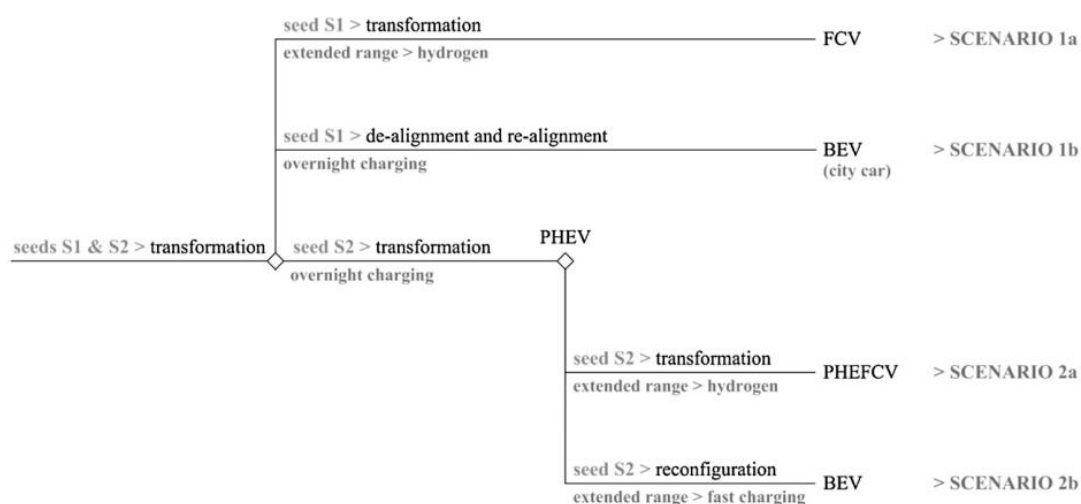
Among all the scenarios made by different researchers for western societies, three of them are enlightening for my further study for China (see Table 1). They are compared in the table below. Description and explanation is made in the following section.

**TABLE 1 SCENARIO COMPARISON**

Scenario	Authors	Driving forces	Tipping points	Difference in results
<b>A</b>	B. van Bree G.P.J. Verbong G.J. Kramer	S1:emissions regulation S2: rising fuel prices	driving force, long trips-short trips	Different models of vehicles (extended BEV FCV or BEV)
<b>B</b>	Boelie Elzen Frank Geels Peter Hofman Ken Green	curb CO2 emission	attitudes of governments, policy	User pattern of car-ownership (pattern satisfy mobility needs, variety of mobility service)
<b>C</b>	Patrick E. Meyer James J. Winebrake	energy security and environmental concerns	favorability of hydrogen market conditions	market penetration of FCV

**SCENARIO COMPARISON**

**SCENARIOS A**



**FIGURE 9 A SCHEMATIC REPRESENTATIONS OF THE FOUR SCENARIOS (VAN BREE ET AL., 2010)**

The two groups of scenarios provide some insights of the various actors who might have play important roles. For carmakers, the options are about experimentation (scenario 1a and 1b) as shown in figure 9 and modularization (scenario 2a and 2b). Currently, many carmakers seem to be dividing their efforts over the various technologies and various dynamics—taking part in experiments, but also introducing modular changes in their current product line-up. Although this may be a suitable strategy

for some carmakers, others may have an interest to speed up a transition (van Bree, et al., 2010). For instance, carmakers who have large models in their production lines may well anticipate that they might fail in meeting future emission standards and have motivation to speed up developments. These carmakers can choose to cooperate with fuel providers and push transition dynamics towards scenario set 1.

For fuel suppliers, in some scenarios see the new entrants. Current fuel supplier (i.e. the oil industry) involved in projects related to hydrogen as a fuel. However, in all scenarios except scenario 1a significant parts (or all) of daily travel is covered using electricity. Therefore, it seems likely utility will play a more important role in personal mobility in the future. In addition, the oil industry can choose to push car manufacturers to speed up development of hydrogen infrastructure rollout as per scenario 1a.

Problems faced by policy makers, including which technology to support. Under normal circumstances, the Governments refrain from 'picking a winner'. However, both technologies require specific policy support to be successful. In case scenario set 1 implement, support should be shifted to the alternative that moves down the learning curve fastest, while keeping an eye on to the extent which the entire market can be covered by each alternative. In case scenario set 2 materializes and PHEVs obtain a large market share, use patterns become important. If a significant part of the market still wants to be able to use their vehicle for making long trips and prefers current refueling practices, specific support for fuel cell technology should be maintained. Alternatively, if short trips are the accepted norm, specific support should target strengthening the electricity grid and perhaps support for fast-charging (van Bree, et al., 2010).

Scenarios in which emissions regulation drives changes (transition seed S1) are characterized by political dynamics and affect the carmaker–consumer relationship only indirectly (van Bree, et al., 2010). BEV and FCVs are reflected as separate models, rather than expansion of existing product lines. This strategy is most likely to achieve initially limited market penetration, as AFVs are limited consumer appeal, especially those desire more BEV or fuel cell vehicles. To connect to an existing product category (conventional vehicles) emerge only when consumers become more familiar with BEV and FCVs.

Scenarios built on fuel price increases (transition seed S2) are market-driven and directly affect the carmaker–consumer relationship. Car manufacturers shift their resources to developing those attributes of AFVs that are most valuable for consumers, as that will yield the largest market share in the emerging segment. 'Upgrading' of attributes that are less relevant for consumers stalls temporarily (van Bree, et al., 2010). Importantly, consumers will have wide range of variety as in the current situation, as changes are implemented in model form extended from the existing lines. This simplifies transition of new technology in new adopting elements.

## SCENARIOS B

Two scenarios are depicted in the study, and they are substantially different.

These two scenarios are not too much different in the first decade. ICE vehicles still dominate, a CEV niche catches a limited market share and hybrid electric vehicles start rising up. In the first case, it seems hybrid electric vehicles appear a bit earlier as due to the firm attitude of the authorities in California. Once they are offered, though, in both scenarios the market for HEV can grow rather fast under the regime pressure to curb CO<sub>2</sub> emissions which is translated into high fuel prices (Elzen, Geels, & Hofman, 2002). The high fuel efficiency of the HEV then makes it an attractive option for a growing customer base.

At the edges, however, there are some worth noticing difference presenting in the two scenarios. In contrast to the first, city authorities in the second scenario are much more pro-active, trying to give at least parts of cities a sustainable flavor and tinkering with all kinds of options for more functional, clean and less intrusive mobility (Elzen, Geels, & Hofman, 2002).

In the niche development of both cases the gap between the starting circumstances set stages of very different development in the future. The first scenario to continue to emphasize a similar pattern of car ownership and use of vehicles to meet the mobility needs. Where the nuisance of car-use gets too large, attempts are made to tackle each problem separately, leading to a variety of technological measures to tamper the negative externalities of car dominance (Elzen, Geels, & Hofman, 2002). This has resulted in higher than average fuel efficiency of the present and a substantial increase in wider varieties of mobility options. Therefore, the carbon dioxide emissions from passenger brought back more than 80% comparing the turn of the millennium. In the second scenario, there is more tinkering, flow pattern at the edge of the emerging pattern draw attention and is stimulated to grow slowly, the combination of various options, is to explore new forms of chain mobility. In the ultimate outcome comparing to the first scenario is that car ownership falls down drastically, while the use of mobility services, whether provided by a public or private operators have been widely adopted. Many travel around the city with CEV, but only a few people own a car, to cover the longer the distance between cities. This has a great effect in net CO<sub>2</sub> emission that it can be reduced to near zero. The reason why the second scenario is so different is that the willingness, even determined to experiment with the novelties. In particular, cities play an active role in searching of an alternative solution, but also tried to learn from the experience in other places. Explicit attempts to treat and development of new systems rather than individual technologies.

In both scenarios, economic instruments and regulation also play an important role, but they do so in different ways. In the first scenario, with economic instrument used in a way, often in most cases, such as in the present, that they have no choice but to continue driving, and pay increasing cost. The main effect of turning up the pressure is that it stimulates industry to develop new technologies that may take away part of the pressure (Elzen, Geels, & Hofman, 2002). Therefore, the overall results become a high-tech variant of this system. In the second scenario, however, economic measures and

regulatory push in at a point where a lot of new alternatives have been clarified, and has also won visibility of the general public in the niche development. Thus, these measures combined with the exploration and learning strategies, leading to rapid changes in the mobility system.

### SCENARIO C

In this paper, *Patrick E. Meyer* (2009) use system dynamics (SD) modeling to better understand and evaluate the diffusion of hydrogen technology in his complementary goods context. The model is focused on the US, through demonstration of this model, they analyze hydrogen vehicles and infrastructure with a respect to the role of technology and policy.

As previously identified, the four scenarios developed under this project explore the dynamics of the vehicle–infrastructure complementary goods phenomenon currently inhibiting the growth of FCVs and refueling infrastructure through three attributes: level of FCV adoption, level of infrastructure development, and favorability of hydrogen market conditions (Meyer, Winebrake, 2009).

In the four scenarios, only the S2 and S3 can produce a successful market penetration of fuel cell vehicles. The only common ground between the two is the favorability of hydrogen market conditions.

In S1 and S4, where the circumstances under which the market penetration do not occur. In both scenarios, the market conditions are not conducive to FCVs. No matter if investing in infrastructure (S1) or vehicles (S4), permanent market share of fuel cell vehicles are not achieved. Therefore, these scenarios suggest that investment affecting one complementary goods may not be enough to speed up diffusion of fuel cell vehicles to occur.

The program shows that incentives must also affect the production of vehicles and infrastructure, to give way for market penetration. Providing greater infrastructure incentives leads to faster hydrogen vehicle adoption and infrastructure construction, but only if vehicles and fuels are also economically incentivized. Investing in initial vehicle purchases will also yield FCV adoption, but at a slower rate, and again, only if vehicles and fuel are economically incentivized (Meyer, Winebrake, 2009). Ignoring the cost of vehicles or hydrogen fuel would not yield adoption.

Therefore, vehicles and fuel-based initiative must be accompanied by infrastructure-oriented incentives; and infrastructure-oriented incentives must be driven by the vehicle and fuel incentives accompanied. Any incentivization that lacks attention to the respective complementary good will yield zero or drastically limited market penetration rates (Meyer, Winebrake, 2009).

If the market penetration of FCVs is to take place in the next half-century, it is very important that investors (federal, state and local governments, transportation fleet, energy and fuel companies, etc.) at the same time act as the first user of FCVs and refueling infrastructure development.



## CONCLUSIONS

In order to apply the proposed theory and methodology in the context of China, I have examined the theoretical background of transition dynamics and socio-technical scenarios' (STSc) previous application in electric vehicles in western societies. The basic theories are discussed in section 2.1. And in section 2.2, STSc have been introduced as an applicable method. Moreover, a literature review of its former application to electric vehicles is conducted in order to find out what characteristics these study have presented and their correlation with its application in China.

Transition theories have been widely used in field of technological change of social function, and some brilliant works have been done on the potential of electric vehicles' transition mainly in western societies. At the heart of the transition theory are three 'levels' and the interactions between them (the multi-level perspective; Kemp, Rip and Schot 2001). MLP practically use the perspective of evolutionary economics, sociology, history, and technology and innovation research. MLP is divided into three levels of analysis and heuristic understanding of system innovation. Essentially, the theories are broad and robust enough to cope with varieties of situations, in which China's context included.

However, possible divergences do exist in interpretations and assumptions of its methodologies. Some researchers try to distinguish phases in transition of socio-technical scenarios based on MLP model, though it may have proved effective in most western societies, it has to be further proved in the context of China, which will be challenged in the next Chapter. At the same time, quasi model of socio-technical transitions and three analytical dimensions of socio-technical regime are also to be looked at closely in the following research.

In the literature review, some important notions and shared similarities have been found among different socio-technical scenarios. And some basic structures of actor network and socio-technical system are generally agreed upon. However, potential diverges do exist between context of western societies and China, especially in policy aspect. Different relationships between industries and governments, on the other hand even between governments will change the basic structure of the actor network .which will result in an influential difference in socio-technical system. In the following Chapter, a case study conducted in the very context of China with STSc will help us gain more insights into this field.

## 3 APPLICATION OF STSc ON A CASE STUDY OF E-BIKES

### 3.1 INSTRUCTION

To answer the theoretical question from last chapter that if the distinguished phases are equally applicable to China's situation, and also if quasi evolutionary model is an effective methodology when applying to China, it is inevitable to conduct a STSc study in the context of China. And in order to find the divergences between context of western societies and China, especially in policy aspect for electric vehicle, this case study has to be somewhat relevant to the transition of electric vehicle. It allows relationships between industries and governments to be examined for basic structure of the actor network, which will result in an influential difference in socio-technical system.

Electric two-wheelers (E2Ws) are gaining widespread acceptance in China; it is arguably the most successful electric-drive market in the world. If E2W success continues, it has the potential to accelerate the development of batteries and larger electric vehicles (EV). Their rapid adoption was a response to the timely convergence of some key trends that started in the late 1990s and urban trip distances rose due to rapidly expanding cities, encouraging faster, longer-range bicycles. Giving the potential for E2W's development, to conduct of STSc study for E2W, another question emerges that what is the role of electric two wheels in the transition of BEV (battery electric vehicle) and under what conditions.

### 3.2 SOCIO-TECHNICAL SCENARIOS OF E-BIKES

#### 3.2.1 FIRST PHASE (EARLY 1990 AND BEFORE)

##### LANDSCAPE DEVELOPMENT

The current era of Chinese participation in global affairs began in earnest in 1971, when China joined the United Nations, and it took another leap forward a year later when President Nixon's visit inaugurated diplomatic relations with the United States. China's economic system has subsequently been reshaped through the dramatic reforms begun by President Deng Xiaoping in 1978 and continued by Jiang Zemin.

During the 1980s and 1990s, China's economy grew at a faster pace than the capacity of the transportation network, which in turn formed a bottleneck imposing a constraint on economic development.

Oil use in China is growing faster than any other energy resource. Between 1986 and 1995, oil consumption increased by 66 percent, compared to 9 percent in the United States. During the same period, oil production grew only modestly, from 2.9 to 3.1 million barrels per day.

##### REGIME DEVELOPMENTS

Before 1990, total annual e-bike production reached only 10–20,000/year. At this time, people knew very little about e-bikes because the average person could only afford a normal bike. E-bike technology was not advanced enough to fulfill the demand of consumers. In particular, battery quality was low in terms of performance and lifetime, and costs were high. In 1987, Electric Vehicle Institute of China Electro-technical Society firstly founded.

E-bike use experienced a surge during the early 1990s due to the government's push for energy efficiency. This period was short-lived however, due to their inability to compete with gasoline-powered scooters. E-bikes again failed to become widespread and gain significant market share. E-bikes were being developed and sold in Taiwan, but they failed to gain considerable market share despite subsidy, in large part because no restrictions were placed on gasoline-powered scooters (Weinert et al., 2007).

#### NICHES DEVELOPMENTS REGARDING ELECTRIC 2 WHEELS

Research into e-bikes production in China first began in the 1960s, though actual products did not appear on the market until the late 80s when consumer demand first began growing. E-bike companies first appeared in Shanghai, Zhejiang, and Tianjin. National Science Board named e-bike as one of 10 main technology projects during 9<sup>th</sup> 5 year plan period in 1991. After Shanghai intended to be first runner in Electric Vehicle (EV) research in 1993, which founded electric vehicle industrialization development center. In the following year, Shanghai lost automobile research bid for developing electric vehicles to Guangzhou; turns to developing e-bikes (via Crane) (Fairley 2005).

E-bike industry structure can be described as open-module. This type of industry structure, coined by Ge and Fujimoto (2004), is also found in the modern computer industry and several other Chinese manufacturing industries (Steinfeld, 2002). In an open-modular (O-M) industry, manufacturers act primarily as assemblers and source components (“modules”) produced by a large decentralized network of suppliers. The O-M structure typically results in increased competition and lower costs.

### 3.2.2 SECOND PHASE (LATER 1990s-2000)

#### LANDSCAPE DEVELOPMENT

In 1993, with oil consumption exceeding production for the first time in its history, China joined the ranks of the world's oil-importing nations. A mere three years later, oil imports had grown from under 100,000 barrels/day to about 300,000 barrels/day, nearly 10 percent of the country's total oil use (Weinert, Ma, & Cherry, 2007).

The closing of state-owned enterprises and liberalization of the housing market, which started in the mid-1990s, gave workers the freedom to live farther from workplaces and create more multi-worker families (Heffner et al., 2007). At the same period, China's rapid urbanization (the flux of rural people into cities), also a product of economic and political changes, created the largest labor force in city than ever before.

An aggressive program of investment in transportation infrastructure has relieved some of the bottlenecks but has also boosted transport demand and private vehicle consumption (Weinert et al., 2007). Transport road length in China grew from 1028 to 1403 km<sup>3</sup> in the 1990s.

Under the pressure of heavy urbanization and aggravating air condition in big cities, in 1995 Prime Minister Li Pong declares support for electric vehicles, leading to “Seminar for E-bike Development in Light Industry General Society. New legislation following in 1999 National e-bike standards passed, creating uniform specifications for bike style electric bike (BSEB) and scooter style electric bike (SSEB). Dept of State Traffic Control Bureau drafts “Road Transportation Safety Law” to allow e-bikes right to use bike lanes as long as they have pedals and speed is below 20 kph in 2000.

The rapid development of China in the past decade has raised the standard of living of its residents. Between 1997 and 2004, average disposable income increased 82% from \$645/year to \$1180/ year (Weinert et al., 2007).

#### REGIME DEVELOPMENTS REGARDING LOCAL POLICY AND INDUSTRY

E-bikes again emerged into the market during the late 1990s and witnessed considerable growth.

Local authorities have established their own regulations. Shanghai was one of the more devoted promoters for electric bike. Since Shanghai suspends license granting to gasoline-powered vehicles downtown in 1996, Guangzhou, Shijiazhuang, and Suzhou ban the sale of gasoline-powered scooters, and many other medium/large cities follow suit in the following years. In 1999 Shanghai began annual inspections of gasoline-powered scooters, eliminating those of which exhaust gas emission was unacceptable- 53,000 were eliminated in 1999-Mayor states desire to replace all motor scooters by electric bike in next 4–5 years. In the same year, Shanghai Economy and Trade Committee lists e-bikes as one of 12 main construction projects (Weinert et al., 2007).

Since crane rolls out first commercial batch of e-bikes (150–180 W motor, 7 Ah battery capacity) (Fairley 2005) in 1997, some companies started to switch their business to electric bike. Some are established companies producing bicycles, motorcycles, electrical appliances, and even toy cars, who shifted to making e-bikes when demand grew. Some of these companies are over 60 years old, but most did not start producing e-bikes until post-2000.

Electric bikes are loosely regulated to a maximum speed of 20km/hr, in which manufacturers rarely comply (Cherry, Cervero, 2007). Although there has been relevant regulation constraining speed of electric bikes, due to demand for higher speed, manufactures manage to go around this regulation all the time.

### 3.2.3 THIRD PHASE (2001-CURRENT)

#### LANDSCAPE DEVELOPMENT

Along with economic development and rapid urbanization, transportation has grown to become one of China's fastest growing economic sectors. Since 2000, China has witnessed a 156% increase in total motor vehicle stock (2000–2007), 51% increase in passenger traffic volume (2000–2007), and 65% increase in freight traffic volume (2000–2007). As mentioned above, following the current explosive trend in vehicle stock, a significant shortage of oil supply may occur in China in the near future. Fuel price has risen substantially from 2002. Gasoline prices in Shanghai increased 45% since 2002 from \$0.39 to \$0.56/liter (excluding inflation).

Vehicle emission pollution has gradually degraded the air in big cities like Beijing, Shanghai, and Guangzhou. Typical pollutants NO<sub>x</sub> and O<sub>3</sub> are heavily above the limit. Though the air pollution type in the big cities has gradually changed from coal dust to mixed pollution, scarcity of oil production and abundance of coal resources render China's energy supply mainly relies on coal combustion. However, while e-bikes provide zero tail-pipe emissions, they do emit pollution from power plants, which are 75% coal fired in China (Cherry, 2006). In addition to that, lead emissions from battery production and recycling have serious health implications in China. Because of poor production and recycling practices within the lead and battery industries, 30–70% of the lead in a battery is lost to the environment.

The rapid development of China in the past decade has raised the standard of living of its residents, between 1997 and 2004, average disposable income increased 82% from \$645/year to \$1180/year. Urbanization and rising income had made urban bus transit losing its competitiveness, further more in 2003, because of the outbreak of SARS many riders shift from public transit (Fairley, 2005).

#### REGIME DEVELOPMENTS REGARDING LOCAL POLICY, INDUSTRY AND USERS

Transport road length in China has doubled from 2001 to 2007. However, this growth is nothing comparing to sales of electric bike, which has grown more than 10 times within the same period, from not as much as 1 million to 14 million in 2006. Shanghai e-bike population reaches 1.35 million, the highest ownership level of any city in China (Zhang et al., 2006). E-bike production in China in 2007 projected to reach 18 million (Wang, 2006). E-bikes price has dropped since their initial introduction while e-bike technology and efficiency has improved. In 1999, the BSEBs were \$310, and fell to \$250 in 2000 due to considerable industrial development. By late 2003, average price dropped again to \$188, with the cheapest models reaching a bottom price of \$125, despite far better quality and performance. The industry grew from under 10 OEMs in 1998 to 481 (according to the official estimate) by 2005 (E-bike Business, 2006).

Contradict to the big picture, some cities held different point of view on expansion of electric bike. 2002 Beijing issues a ban stating they will cease offering e-bike licenses beginning 2006 in order to promote automobile development, Beijing Communicative Administration Department (Peoples' daily, 2002). At the same year Fuzhou government bans electric bikes from streets but is later sued by e-bike OEMs and citizens, raising the profile of e-bikes throughout China. In November 2006,

Guangzhou became the third city in China to ban e-bikes, under advice from the traffic management bureau citing traffic safety concerns (XinhuaNet, 2006). This is primarily because e-bikes, while becoming faster and heavier, are very quiet. When operating, they are virtually imperceptible by ear, especially to vehicles, which makes e-bike users vulnerable but also dangerous to pedestrians. Electric bikes are also not the most efficient users of scarce road space. While e-bikes can move more people per lane than cars, buses move more people per lane than e-bikes (Cherry and Cervero, 2006).

However, in the same year Beijing finally reversed itself in 2006. Because of traffic congestion in urban areas drives regulatory support of electric bikes, also the urgent need to improve air quality inside cities, especially before the 2008 Olympic. But this hostile policy impacted consumer purchase decisions during these key e-bike growth years, resulting in lower e-bike share than many other cities.

Several surveys and research have been conducted in Shanghai and some middle sized cities about impacts of this surge in E2W. A survey in Shanghai (Cherry and Cervero, 2007) suggest that A large portion of electric bike users previously rode bicycles for the surveyed trips, but would use bus now if electric bikes were unavailable. This implies that a large group of travelers shifted from bicycle to electric bike in place of shifting from bicycle to bus. While another survey conducted in Shijiazhuang (Weinert, Ma, Yang, & Cherry, 2006) concludes that almost 70% e-bike users have no plan to switch to another transport mode in the next year, and their most probable switch would be a better e-bike or a car. However different conclusions were drawn from different research, what they agree with each other is that once they were exposed to motorized travel, human-powered mobility was generally not considered a viable option.

Another interesting aspect is that faster speed and less effort were primary reasons for people to use E2W. However, men and women hold different attitudes towards owning faster and more powerful e-bike, in which men are far more motivated to have a more powerful E2W than women (Weinert, Ma, Yang, & Cherry, 2006).

#### NICHES DEVELOPMENTS FOR EV

In the 10th Five-Year-Period, the Chinese central government spent \$20 million per year on FCV vehicle R&D. The Chinese Academy of Science spent \$12 million in three years to support hydrogen energy technology.

Innovation in Li-ion battery technology for EVs could be accelerated by the shift to VRLA to Li-ion in the E2W market. Because of similarities between E2W and EV batteries, experience gained in R&D, manufacturing, and operation in the E2W battery market will transfer to EVs. At least three Li-ion battery companies are making batteries for E2Ws with the strategy to build up production volumes with the E2W market and eventually shift to producing batteries for EVs (Weinert et al., 2008).

### 3.3 CONCLUSIONS

In this chapter, E-bike's large scale introduction in China have been examined and studied through application of STSc method, which is expected to have three contributions to this paper. The first one is that it complements our knowledge about the dynamic interrelation between the landscapes, regime and niche development in the very situation of China, which also contribute to answer the empirical research question we have at the beginning. Another contribution of this study is to examine the theory itself in its application, so to speak, to gain more insights of the theoretical question that to what extent this method could be applied. Last but not least, it is relevant to know what possible role E2W can play in the transition of BEV and how to realize that.

Overall stereotype of E-bike's transition can be perceived as a combination of 'Endogenous renewal' and 'Purposive transitions', in which highly coordinated response is obvious in conscious efforts of both central and some local governments, while the uncertainty arises in the location of this transition between internal and external adaptation. On the one hand, bike and e-bike as two parallel products, each owns their stable set of users now. Conventional bike industry is not replaced but coexists with e-bike industry in the market. That means some external forces come into play in this field. On the other hand, some manufacture of conventional bikes did transform or expand their production lines to adapt to this new situation. Thus, a combination of external and internal adaptation and coordinated response are major characteristics of this transition. More specific observations regarding to transition model in China's context are summarized as following:

Firstly, economy growth enjoys a fast pace in China, along with that decision making process is also faster comparing to most of developed country. This might suggest an accelerated transition model for China, at least in this E2W case. However, this can also be caused by this maturity level of this applied technology, which would be justified in the following research.

Secondly, top down policy plays a bigger role here in China. Considering about the centralized role of national government, this result is not a surprise. Local authority would tend to follow the direction that the central government pointed out, since strong dependence of local governments.

Third, policy interpretation and implement of local authorities are important. When central government doesn't give direct instructions, or show clear intentions, local governments would play key roles regarding policy making and implementation. Addition to that it is almost impossible for the central government to map out the pathway for each region of the country, policy interpretation became crucial. And it is also wise thing to do because of the varied conditions of different region, it is especially true when it comes to the large gap between cosmopolitan cities and poor rural areas.

Addition to that, how varied local authorities react throughout the process is observed in the case study. Some cities take the lead and actively promote E2W development at the very beginning, and some cities hesitated in this process and issued bans in the midterm, and more other cities choose to wait and see and follow the trend. This brings up a question that how the local authorities' manners

of administration would affect their attitudes and policy trend towards different industries, which may correlated with transition managing style of external adaptation and internal adaptation.

As implications for BEV development, it is no wonder that China is using e-bike as stepping stones for development of EV. Although it remain unclear when this decision has been made, since the wavering attitudes towards E2W began to emerge in early of 2000s. However, government is holding a more determined attitude to promote EV comparing to E2W, as they are also facing a case with bigger difficulties: public acceptance, infrastructure limitation and technology constraints.

Except for promising potential of this transition from E2W battery to BEV battery, one cannot afford to ignore the fact that these two types of batteries differ in many ways, see table 2. On the one hand the performance requirement for the two types of batteries varied to a large extent. On the other hand, the current high cost of batteries relative to transmission/engine drivelines is the major barrier to BEV commercialization, which is shown in the large cost difference between E2W and EV battery system.

**TABLE 2 COST COMPARISON OF BATTERY SYSTEMS FOR E2V AND EVS (WEINERT ET AL., 2008)**

	E2W battery system		EV battery system	
	VRLA <sup>a</sup>	Li-ion	VRLA	Li-ion
<b>Cost (\$)</b>	100	420	800	4850
<b>Mass (kg)</b>	20	8	270	90
<b>Lifetime (yr)</b>	3	9	2	6
<b>Volume (L)</b>	10	5	110	60
<b>Max continuous power (Kw)</b>	2.4	3.8	27	44
<b>Battery energy required</b>	E2W=0.84kWh		EV=9.6kWh	

<sup>a</sup> valve-regulated lead-acid

In this case a smooth transition should not be expected, but a technology breakthrough of E2W is more likely to impose a significant influence on battery development of BEV. Nonetheless, technology breakthrough of E2W's battery technology is not the only way it can contribute to the development of BEV. As wide spread use of E2W has already taken place in China, we can also see an expanding experimenting ground for BEV. Since the number of E2W in China is increasing, the validity and significance of battery experiments also rises. On the other hand, expectation for E2W's performance keeps rising because of intensive competition, so manufactures are also motivated to improve its relevant attributes, e.g. range, lifetime. However, this situation requires a close cooperation between



E2W's manufacture and BEV's designers, or least E2W with a strong ambition and competence of producing EV.

From user perspective, taking several questionnaires into account, the current E2W user populations would not be the targeted BEV user population at least in the short term. They are more likely to switch to public transportation, conventional bike, or even gasoline automobiles. This is largely due to the fact that the high price of electric vehicle now is far from acceptable, which is mainly composed by its battery. However, there is also another side of the story. Some complaints are very popular among the e-bike users, such as limited battery range constrain travel distance, E2W are too quiet that even compose safety problems, battery is hard to have a 'long and healthy' life, etc. E2W share some similar problems with EV (especially BEV), which are exposed to the users and transport system. Yet still, the public showed a considerable level of tolerance towards these pitfalls, which is demonstrated by the fact that the e-bike population is still increasing. Thus, it is reasonable to assume the transition might be more coherent in user behavioral pattern, travel mode and safety perception.

This transition can also be relevant in infrastructure's construction. As a shared problem of E2W is that its limited range has caused inconvenience and incompetence comparing to gasoline powered scooter, which is also the main shortage of EV. It is rewarding for the government to launch a series of charging facilities for E2W, at the same time make sure they are technically transformable to that of BEV. This will contribute both to BEV and E2W. On one hand, it encourages use of E2W, since it solves the greatest obstacle of E2W in practical use. On the other hand, it serves many purposes for development of BEV. First, it resolves potential users' worries of lack of complementary facilities of EV, when they notice the new equipment in the fuel station and know they are transformable. Secondly, it can reduce the cost of building new facilities. Also, if introduction of BEV has to be postponed it is also safer to make an attempt like this first. Thirdly, it helps accumulating experience of building and running electricity charging station, which is important in a country like China, it's possible some special actions have to be taken to prevent theft and vandalism.

However, from environmental concern, as the short term goal of China can be promoting cleaner alternative vehicles, such as electric vehicles, to decrease air condition problems in big cities and to alleviate oil import dependence. However, more changes are required in the long term future to provide sustainable energy production in order to solve the key environment problem.

## 4 LANDSCAPE DEVELOPMENT OF ELECTRIC VEHICLE IN CHINA

At the end of last chapter, environmental concern for China has been brought up. Is environmental concern the driving force of electric vehicle's transition in China? Or there are other problems which are more urgent to solve by electric vehicle? To find out the driving forces behind the tremendous potential change of China we have to look at the broad context of China from macro point of view. On the other hand, it remains questions that if China is ready to embrace electric vehicle in its large scale introduction and also, if China's expectation for EV will be realized under the current energy structure. To get more insights into these questions, in this chapter, we will discuss energy, environment and transport situation of China.

### 4.1 CURRENT ENERGY STATUS OF CHINA

World energy consumption almost doubles in 34 years from 1973 to 2007, and China's energy consumption doubles in shares, which means, China's energy consumption has increased four times during this period. This is even not a surprising result considering China's economy development and its responsibility for 1/5 population of the whole world. However, this phenomenon has to be zoomed in and more specific analysis is needed.

China's total energy consumption in 2008 reached 1.995 billion of oil equivalent (Mtoe) tonnes, coal accounted for 70%. In 2008, the total consumption of 274 million tonnes (3% increase compared to 2007), of which about 40 Mt of coal has been imported. In the first half of 2009, approximately 48.2 Mt were imported, an increase of 126.3 % (State Grid Corp. Power Economic Research Institute, Jiang Liping, 2009). Total oil consumption in 2008, mainly for use in the transport sector, reaching 360 Mt about half the gross domestic production. China, after the United States and Japan is the world's third largest oil importer. Recent estimates by the Energy Research Institute (ERI) of China suggest that by 2020, the oil consumption may reach 620 Mt, of which approximately 60% will have to be imported (Hu et al., 2009). Although its share of total energy consumption increasing every year, natural gas accounted for only 3.63% total energy consumption in 2008. The government is seeking to increase that share to 10% by 2020 (State Grid Corp. Power Economic Research Institute, Jiang Liping, 2009). In the following sections, some of the major energy sources, such as oil and coal consumption would be examined.

#### 4.1.1 OIL

Since 1993 China has become a net oil importer. In 2006, oil import amounts to 1.63 million tons, 47%, of its total oil consumption. No significant improvement is expected in the country's oil production capacity, while oil consumption will maintain rapid growth. On the other hand, it is estimated that China's oil production is hardly likely to increase in the future and will actually decline gradually to 164 million tons in 2030 (EIA, 2007).

For future vehicles on the road, He et al. (2005) estimated that the total fuel consumption may be 363 million tons in 2030, if in the future fuel economy standards maintained at the current level. Under conservative fuel economy and High improve conditions, according to Wang et al.'s (2006) projection that high oil demand in rural areas from vehicles, including motorcycles and vehicles amount up to 498 million tons in 2030,. Even expectation of the lowest growth in vehicle scenario and actively improved fuel economy, fuel demand will remain as high as 354 million tons (see Table 3). These figures are much higher than the 250 million tons from the INET (Institute of Nuclear and New Energy Technology, 2004), 290 million tons, ERI (Energy Research Institute, 2005) and EDMC (2006) 310 million tons. Some of these differences exist in the economic growth scenario, vehicle diffusion, environment and fuel economy improvement.

**TABLE 3 OIL DEMAND OF MOTOR VEHICLES IN CHINA (2010–2030) (MILLION TONS)**

	He et al. (2005)		Wang et al. (2006)	
	Non-control	LS	HS	
<b>2010</b>	132	130	128	166-168
<b>2020</b>	227	208	191	262-295
<b>2030</b>	363	308	277	354-498

Fuel tax was widely accepted as one of the most effective financial measures to influence driver s' behavior. Germany, France and Italy have a higher fuel tax rate, gasoline tax is far more than diesel fuel. For example, based on fuel prices of November 2005 in Germany, France and Italy, gasoline rate 201%, 199% and 163%, respectively, and the corresponding rates were 97%, 90% and 76%. These different rates in the EU provide incentives for new powerful diesel car.

Fuel tax is the most well-known for difficult birth in China. In 1997, the Chinese National People's Congress approved the 'Highway law', in which road tolls and other costs associated with transport were replaced by vehicle fuel. However, the fuel tax is still controversial. Last year, the State Department implemented fuel price and tax reform from January 1, 2009. The notice from the Ministry of Finance and the State Administration of Taxation includes increasing the unit tax rate of fuel excise tax and adjusting the tax policy for fuel destined for special purposes (Hu et al., 2009).

Factors affecting the projections for transportation energy use include urbanization and expansion of the middle class, efficiency improvements, consumer preferences, costs, and lag times associated with infrastructure development (EIA, 2007). In short, no further efficiency improvement with the current pattern to energy-saving measures such as trip demand management, oil demand for on-road vehicles 2030 was likely to be 300-350 million tons, 3 times of the present consumption, nearly 2

times of the total oil production at that time. This will be an unbearable burden of the global oil market and China's energy security.

#### 4.1.2 COAL

China, as the largest producer of coal energy in the world, the products mainly serve for domestic demand and a slight amount to export. As shown in Fig.10, from 1971 to 2007, energy consumption of China has been increasing. And this can be directly reflected from the rise of coal production, almost every increasing number of total energy consumption has a major contribution from coal consumption, since, the other energy source remains relatively stable. In Fig.9, it's obvious from 1997-2000 a stable and even declining trend of energy production can be found, while after 2001 a radical rise have taken place ever since. To find the reasons behind the sudden pause and the radical rise will give us more insights of the dynamic nature of China's energy consumption. This decline in energy consumption in recent years mainly due to:

First, there has been reduced demand for energy products. The first time the nationwide buyer's market has grown to its strength since 1997, together with the Asian financial crisis, weaken domestic demand, resulting in reduced demand for energy products.

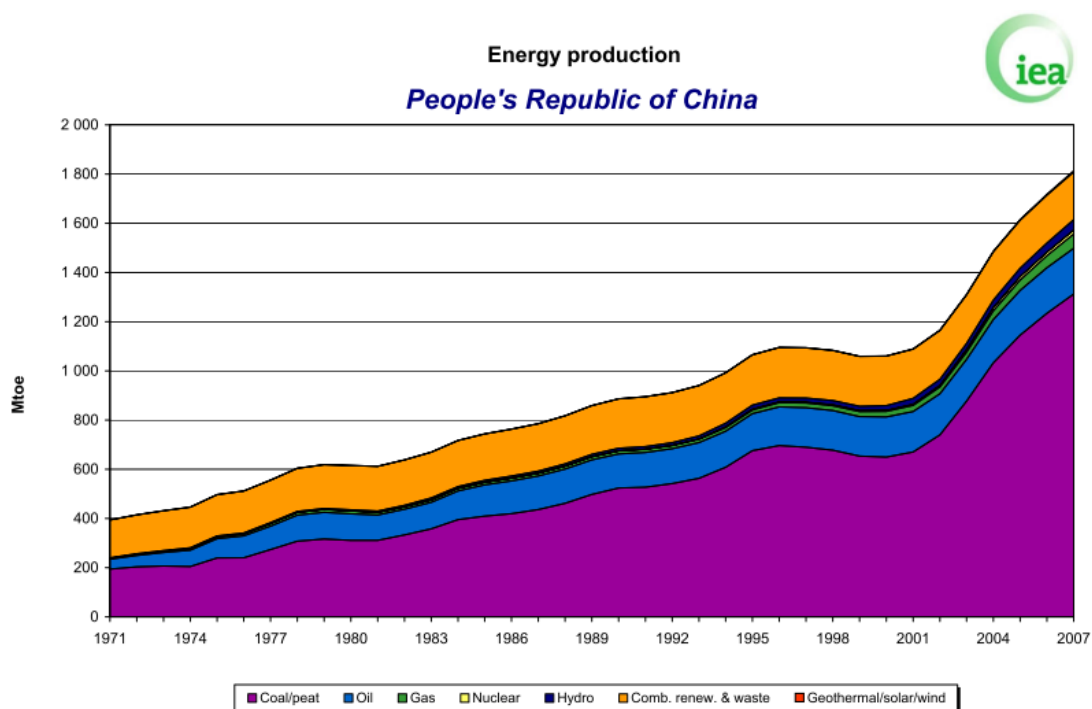


FIGURE 10 ENERGY PRODUCTION FROM 1971-2007 IN CHINA (EIA, 2007)

Second, change of industry structure result in decreased energy consumption. 1997-1998 and 1999, the proportion of tertiary industry (service industry) respectively 30.9%, 32.1% and 33.0%, increased year by year. As energy consumption per unit output of tertiary industry is far less than the industry,

thus driving down the overall energy consumption. Also within the industry, light industry growth has been faster than heavy industry.

Third, energy efficiency has improved. In recent years, due to adoption of new technology, while abandoning inefficient equipment, coupled with the extensive application of energy-saving technologies and management improvement of energy efficiency in China basically had been increasing. This can be seen from China's coal consumption per unit of electricity in 1997-1998 and 1999, for 375,373 and 369 grams respectively, has decreased year by year.

However, ever since 2001 China's energy consumption elasticity coefficient is greater than 1. In 2002, China's energy consumption growth rate is 9.9%, while the economic growth is 8.3%, energy consumption elasticity coefficient (consumption growth rate/economic growth) is 1.19, which is the second time since the economy reform (the first time in 1989, the year of energy consumption elasticity coefficient 1.02). Energy consumption grew faster than economic growth, the main reasons could be:

One is that investment growth in steel, cement, electrolytic aluminum industry, and the rapid expansion of high energy industry, resulting in energy consumption to grow rapidly. The rapid growth of energy-intensive products will inevitably bring about the rapid growth of energy consumption.

The other is that rapid growth of civil energy consumption has driven entire energy consumption growth to accelerate. Ever since 2002, sales of household appliances (e.g. private cars, mobile phones etc.) has rapidly grown, coupled with gas and natural gas in households in the widespread use have contributed to the rapid growth of the entire energy consumption.

### Fuel shares of TPES in 2030 for Reference Scenario and 450 Policy Scenario

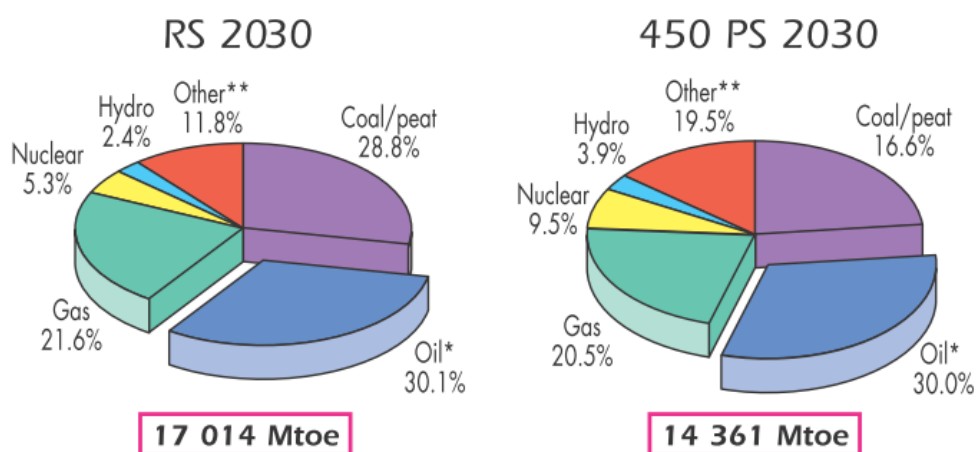


FIGURE 11 SCENARIO AND 450 POLICY SCENARIO FOR FUEL SHARES OF TOTAL PRIMARY ENERGY SUPPLY IN 2030 (IEA, 2009)

RS: Reference Scenario (based on current policies) 450 PS: 450 Policy Scenario\*\*\* (based on policies under consideration)

\*Includes international aviation and international marine bunkers. \*\*Other includes combustible renewables & waste, geothermal, solar, wind, tide, etc. \*\*\*Based on a plausible post-2012 climate-policy framework to stabilise the concentration of global greenhouse gases at 450 ppm CO<sub>2</sub>-equivalent.

F. Gerald Adams (Adams, Shachmurove, 2008) build an econometric model of China's energy economy, based on the energy balance and use the model to forecast China's energy consumption and imports in 2020. It is important to view the supply and imports, from quantitative and growth rate from dimension. Domestic energy production has relatively slow rate of growth comparing to consumption rate. Therefore, as coal and crude oil imports will increase significantly during the period to 2020. Crude oil imports from 2002 to 2010 increased by about 3 times, again from to 2010 to 2020. These estimates, of course, depend greatly on our assumptions for domestic production as well as consumption, so that presently unforeseen increases in domestic supplies could reduce imports, ton per ton (Adams, Shachmurove, 2008).

It is interesting while comparing to 450 policy scenarios of by IEA, contrary to China's increasing demand for coal, and it is obvious that that international expectation for proportion of coal consumption is to decrease. That is because the low efficiency of coal energy, which will be further illustrated in *environment* section. It is likely that in future China is going to receive more pressure from international society if the situation is going uncontrollable of coal consumption. Measures have to be taken to restrain this situation in order to find cleaner and more sustainable energy resource.

#### 4.1.3 NATURAL GAS

It is estimated that the total gas resource in China is 10-13 trillion cubic meters (Energy Research Institute, 2004a). The end of 2007, China has proven natural gas reserves of only 18,800 billion cubic meters, ranking the world's No. 18 (BP, 2008). Despite predictions from the other side is much higher than this figure, one of the International Association (Cedigaz, 2007) projected to reach 37,200 billion cubic meters. July 2006, China announced the discovery of new areas in the Pearl River Delta natural gas resources, a preliminary estimate of reserves of more than 1,000 billion cubic meters, China's largest offshore natural gas resources (Xinhua News Agency, 2006). Proven natural gas reserves with the new value are also found in a increasing manner.

Currently, natural gas consumption accounts for about a 3% of total energy consumption. Including the construction of power plants, Chinese gas power installed capacity more than 1.4 million kilowatts. Although the gas power plants are with less investment, high efficiency, taking into account the current price of domestic coal and natural gas, coal or natural gas's price advantage is obvious. And coal-fired power generation is more competitive than gas turbine combined cycle power. However, in the coming years, as the infrastructure of natural gas and energy prices, changes in natural gas demand growth is expected to be faster than coal and oil. By 2020, China's total installed capacity of natural gas could reach 600 million kilowatts, and the non-power sector consumption of natural gas will also have huge growth (Energy Research Institute and the State Grid Corporation of

China, 2007). It is somewhat faster than the assumption of the International Energy Agency , they expect gas power generation capacity by 2015 will reach 3.1 million kilowatts, while the 2030 will be close to 1,000 kilowatts (IEA, 2007a). China's domestic natural gas production could not keep up with growing demand, which make natural gas imports will become more important.

As natural gas from Russia, the Middle East, Central Asia and Latin America is influenced by the international oil and gas market price fluctuations and the impact of transport conditions, China's oil and gas imports faced with certain risks. Some analysts believe that, in regions neighboring China, Southeast Asia, oil and gas production growth potential is limited, for this reason that some people think that future of China should not be oil and natural gas as a substitute for coal (Rong-Hua Liu, 2006).

#### 4.1.4 OTHER ENERGY SOURCE

##### 4.1.4.1 HYDRO

China is the largest hydro power producing country in the world, about 15.3% of hydro power was produced in China in 2007. China is a large country, which encompasses vast geographical diversities that could enable hydro project of different scales. And such projects are encouraged nationwide especially in some rural area where possess hydro natural power. Engineering technology of this field has been sharpened during this development process, together with the nation's efforts for developing sustainable energy in research, the use of hydro power is expected to grow in the coming future.

It is an international trend that hydro power projects have widely diffused worldwide. While China's development speed in this area has outgrown the average speed of the world. Thus hydro energy is expected to be the most promising sustainable energy source to be developed in China.

##### 4.1.4.2 NUCLEAR

As of 2008, China has 11 nuclear power plants located in four different reactor sites. China has also participated in the nuclear fusion reactor, ITER project. China currently has 9,100 megawatts of nuclear capacity and has approved the construction of additional reactors to increase output to 25,400 megawatts (IEA, 2007). The country is expected to build around 22 reactors in the five years ending 2010 and projected to build 132 units after and has the most aggressive nuclear power expansion program in the world (IEA, 2007).

Nuclear power plays an important role, especially in the coastal areas remote from the coal region and the rapid development of economy. In general, the demand for nuclear power plant can be close to center, and the wind and hydro power are far from domestic needs. Nuclear-building projects, was commenced in 1970, has shifted to a stage of rapid development. Technology has been drawn from France, Canada and Russia, with local development based largely on the French element (World

nuclear organization, 2010), and the latest technology acquisition has been from the USA (via Westinghouse, owned by Japan's Toshiba) and France.

#### 4.1.4.3 SOLAR

Another key technology trend is the ever-faster drop in the cost of solar power. Solar energy in China is abundant. In western China, there are more than 3000 sunshine hours per annum (Chang et al., 2003). Taking into account the vast area and low population density, small-scale energy facilities, such as the PV systems are more cost effective than expansion of the existing power grid. Therefore, the photovoltaic power generation system that play important role will be developed in the western region of mainland China.

The higher cost and shortcoming of lower energy density (approximately 1 kWp/m<sup>2</sup>) and time dependency limit the application of solar energy (Chang et al., 2003). However, progress may continue in the photovoltaic industry and reasonable improvement in cost reduction can be expected in the near future. Gap between laboratory and industrial equipment performance is narrowed. This will result in a high-performance of low-cost solar photovoltaic system, the birth of a new generation. We expect solar costs to drop 80 to 90 percent over the next decade. This means that by 2020, unsubsidized solar power will be cheaper than subsidized coal, oil and nuclear (EVworld, 2010). However, the transformation of infrastructure will require government to help with proper policies.

#### 4.1.4.4 WIND

Wind energy has been used for centuries in China. In ancient China, windmill, wind power has been used for pumping and grinding grain. Today, the windmill's modern equivalent, wind turbines produce electricity from wind. Advanced wind turbines technology is capable of producing for the residential, commercial electricity, and even public utilities. Wind turbines can be used as standalone applications, and can also be connected to a public network, even with the photovoltaic (solar cells) system. For utility-scale sources of wind energy, a large number of wind turbines are built close together to form a wind farm, and several electricity providers in China today use wind farms to supply power to their customers (Chang et al., 2003). (e.g. Nan Ao Wind Farm, Shan Wei Wind Farm).

#### 4.1.5 ELECTRIFICATION OF CHINA

China, with strong political will, extended its electricity grids and exploited the country's hydropower and solar potential. China achieved an electrification rate of 99.4% in 2009, with rural areas reaching 99% and urban areas 100% (IEA, 2009b). In the past 10 years, rural electrification has slowed down because of nationwide electrification is nearing completion. Instead, in this period focus is on modernization, service and improving the quality of poverty reduction and introducing the innovative technology solutions in the vast western region of the country remaining non-electrified remote areas. China will now focus mainly on the use of decentralized power systems to supply, by the end of 2020, most of the people who are still without electricity (Niez, 2010).



By the end of 2008, China's total installed power generation capacity amounted to 793 GW, an increase of 10.4% since 2007. In 2009, an additional 80 GW is expected to be installed, and by 2020 total capacity should more than double, reaching 1 600 GW with thermal power accounting for 65% (State Grid Corp. Power Economic Research Institute, Jiang Liping, 2009). Owing to its coal-dominated energy supply structure, thermal power generation capacity accounts for more than 75% of total installed capacity and China ranks first worldwide in hard coal production, producing 47.4 % of the world's total hard coal in 2008 (IEA, 2009c).

During the 11<sup>th</sup> Five-Year Plan (2006-2010) the Chinese government plans to reduce energy use per unit of GDP by 20%. In this context, a reduction of 1.79% was achieved in 2006, 4.04% in 2007 and 4.59 % in 2008 leading to a cumulative reduction of 10.4% (Energy Research Institute Han, Wenke 2009). Additional efforts will be needed to reach the 20% target.

#### 4.1.5.1 CURRENT STATUS

Rural Electrification Authority policy planning and financing located in the central and provincial levels, but also belong to different government institutions. Related responsibility may differ in areas, it is often difficult to find a way in complex administrative system.

In 1996, with the Electric power law introduction, the state introduced preferential policies for rural electrification, providing support to the ethnic minority settlements in remote areas and heavily poor areas. In addition, the central government promoted the development of water resources in rural areas, construction of small and medium-sized hydropower stations, to promote rural electrification. The state encourages and supports solar, wind, geothermal, biomass and other energy use, to increase the supply of electricity in rural areas. In 1999, the State Council approved the "Notification on Accelerating the Reform of Rural Power Systems and Enhancing Rural Power Management" (the State Council Doc. No. 2 1999), which carried out a comprehensive structural reform of the management of rural electrification which affected rural power marketing, rural power prices, power grids, investment and management. The reform introduced, among other things, the practice in the same province, and the rural and urban residents will pay the same in electricity prices. In 2002, the State Council's "Circular on Program of Power System Reform" (the State Council Doc. No.5 2002) introduced the practice of "Separation of Power Plants from Grid, and Bidding for Generation", and the State Power Corporation was split into the two power grid companies and five power generation groups. In 2007, the General Office of the State Council issued "Views on the Implementation of Deepening the Reform on Power System during the Eleventh Five-Year Plan Period" (The General Office of the State Council Doc. No.19 2007), which standardized the restructuring of power enterprises at the county level, and encouraged the involvement of independent power companies. Since 2007, the State encourages all types of investors to invest in rural power grids.

**TABLE 4 UN-ELECTRIFIED HOUSEHOLDS AND POPULATIONS (EARLY 2006)**

No	Province	Households	population	No	Province	Household	Population
1	Yunnan	503003	2189361	18	Shanxi	12744	50976
2	Sichuan	476707	1939150	19	Ningxia	12664	49650
3	Tibet	212431	1200668	20_1	Liaoning	10854	33403
4	Inner Mongolia	186658	746632	20_2	Dalian City	9821	44670
5	Guangxi	163302	727892	21	Fujian	4797	20901
6	Chongqing	153699	552297	22	Hebei	2800	11909
7	Gansu	123936	523394	23	Hunan	31074	124595
8	Henan	134472	505372	24	Hainan	8700	35000
9	Qinghai	89488	495372	25	Jiangsu	--	--
10	Shaanxi	126838	477831	26	Anhui	--	--
11	Guizhou	111830	466350	27	Beijing	--	--
12	Xinjiang	95300	415700	28	Shanghai	--	--
13	Hubei	72947	243482	29	Tianjin	--	--
14	Guangdong	47938	238417	30	Jilin	--	--
15	Jiangxi	45854	191434	31	Zhejiang	--	--

Source: EU-China (2009)

#### 4.1.5.2 ELECTRIFICATION OF RURAL AREA

In China, the traditional method of providing electricity to rural areas, is mainly through grid extension. However, transmission lines often led to long lines in a small load and huge losses. Currently, most of the region without electricity in the western region and eastern coastal areas of islands, are far away from the grid. These areas are mostly abundant in the renewable energy resources (water, solar and wind power), which can economically provide electrification of remote areas. In rural China, electricity is supplied through three channels: a county is connected to a national grid, or is supplied through local dispatch, or is self-supplied. Following this pattern, China implemented the “Brightness Program” and the “County Hydropower Construction of National Rural

Electrification”, using small hydropower, wind and solar power generation for the electrification of rural areas (Niez, 2010). Table 8 illustrates the characteristics of the five main periods of Chinese rural electrification.

**TABLE 5 STAGES OF RURAL ELECTRIFICATION IN CHINA BETWEEN 1949 AND 2009**

Period (years)	Percentage of rural population with access to electricity	Expected end-use as formulated by government	Principal means of electrification	Percentage of electrified rural households NOT connected to national grid
1949-1957	Very low	No formulated expectation	Locally manufactured small hydropower	90 (estimation)
1958-1978	61	Irrigation, agricultural processing, rural industry	Small domestic hydropower (simple technology and imported from former Soviet Union)	80 (estimation)
1979-1987	78	“Rural economic development”, better rural living standard	Small hydropower (improved domestic technology), small thermal applications	60 (estimation)
1988-1997	97	“Support the industrialization of the rural economy”	Grid extension, small hydropower (improved domestic technology)	37 (for 1997; by county [Peng &Pan, 2006])
1998-present	>99	Use of rural electricity be no longer limited by technical insufficiencies or non-standard price	Grid extension, small hydropower, other renewable energies e.g. PV, PV/wind hybrid, solar home systems (SHS), small scale wind turbines	22 (for 2000; by county [Peng &Pan, 2006])

Providing electricity to populations in remote, off-grid areas is a clear objective of the ongoing 11<sup>th</sup> Five-year Renewable Energy Plan, primarily featuring the deployment of clean and renewable energy

in the following order of priority: small hydro, PV village systems, PV/wind hybrid systems, small wind turbines, and solar home systems (Niez, 2010). With the potential of small hydropower projects, it will be adopted as a priority in the development, because of the lower cost per kilowatt produced. In the areas absence of water resource, solar photovoltaic small station / wind hybrid station, small wind turbines, solar home systems will be installed to provide electricity by the end of 2010 to more than 1 million families. Target areas are Tibet, Qinghai, Inner Mongolia, Xinjiang, Yunnan and Gansu. Today, one-third of the total rural electricity consumption is supplied by local small hydropower (Chen Lei, 2009).

For decades, China's focus is to ensure urban and industrial power. Therefore, the gap between the service supply of urban and rural areas has been growing. Relatively less developed rural areas, has slow growth in electricity consumption, seasonal and fluctuating over the day. Long transmission line with low load density is of high costs, which lead to power supply to rural areas with little or no revenues. In addition, a number of county's management electricity suppliers in the past, are heavily indebted and their workers are of less skill. These high operating costs have driven potential investors away. Centralized structure, rooted in history and politics, resulting in network expansion, for which construction costs transmission loss and maintenance costs are high, instead of dispersed solution. However, with its goal to electrify an extra 10 million people by 2020 through the use of locally available renewable energy resources, and the sharp fall of application costs for renewable energy systems during the last decade, China is striving to become the world market leader for PV and wind energy technology (Niez, 2010). To lower cost for growing domestic demand electricity supplies will have strong incentive for greater industry involvement.

#### BRIGHTNESS PROGRAMME AND TOWNSHIP ELECTRIFICATION PROGRAMME

In 1996, the then State Development Planning Commission (SDPC) (known as the National Development and Reform Commission, NDRC, since 1996) launched the so-called "brightness program" to provide about 23 million people live in electricity in remote rural areas, services and resources based on renewable energy, distributed energy systems such as hydro power, solar and wind energy by 2010. Our goal is to provide 100 watts of capacity per person. In the pilot phase (1999-2002) in Inner Mongolia, 5,500 hybrid solar / wind / battery home systems, 100,000 solar home systems(SHS) in Gansu, in Tibet, 30 PV / battery villages power systems and 11 000 SHS, has been installed. It is estimated that some 50 000 people have been supplied with the electricity. As part of the Brightness Program, the so-called "Township Electrification Program" (2002-2005), with a total investment of CNY 4.7 bn (USD 0.69 bn) consisting of special central and local government funds, was used to supply electricity to 989 rural townships and villages throughout western China [c]. By the end of this program, 1.3 million people had access to electricity by means of PV, PV/wind hybrid, and small hydropower stations (NDRC, 2008).

#### GOLDEN SUN PROGRAMME

In late July 2009, the Ministry of Science and Technology (MOST), the Ministry of Finance (MOF), and National Development and Reform Commission (NDRC) jointly announced to financially support the deployment of up to 500-600 MW of large-scale solar PV in both on-grid and off-grid areas by 2012 (Niez, 2010). The program aims to limit of 20 MW for each province provinces. On-grid solar power project investment will be 50% provided by the Government and for off-grid system, will be subsidized 70%. Subsidies are conditional on the requirement of 20-year life of the installation

## 4.2 ENVIRONMENT SITUATION OF CHINA

China is the world's most populous country. Their energy use has rapidly increase in the past two decades, because tremendous annual economic growth of 8-10% per year. Therefore, future development of China is of great significance to the future of the global energy system and its associated environmental impacts (Gielen, Changhong, 2001).

Coal use is the source of a number of environmental problems (Gielen, Changhong, 2001). Local pollution problems related to coal use, such as sulphur dioxide (SO<sub>2</sub>) emissions and particulate matter (pm) emissions, are well-known, e.g. (Qian and Zhang, 1998). Recently, nitrogen oxides (NO<sub>x</sub>) in the city, has become local air pollution problems due to rapid growth in road transport of oil consumption. In recent years, carbon dioxide (CO<sub>2</sub>) emissions related to the use of coal received much international attention.

Two-thirds of world emissions for 2007 originated from just ten countries, with the shares of China and the United States far surpassing those of all others. Combined, these two countries alone produced 11.8 Gt CO<sub>2</sub>, about 41% of world CO<sub>2</sub> emissions. In 2007, China overtook the United States to become the world's largest emitter of CO<sub>2</sub> emissions from fuel combustion.

### 4.2.1 EMISSIONS FROM TRANSPORT SECTOR

China's energy supply comes mainly from coal burning, but the type of air pollution in large cities has gradually changed from a mixture of coal dust pollution to mixed pollution. Vehicle exhaust pollution has been gradually degraded air in the big cities such as Beijing's Shanghai and Guangzhou. Typical pollutants nitrogen oxides and ozone are above limits. The rapid increase of private cars emissions, share of air pollution has a sharp rise, especially in large cities 80% of CO, and 40% NO<sub>x</sub>, see table 6.

TABLE 6 VEHICLE EMISSION POLLUTION SHARES OF SELECTED CITIES (%) (THOMAS, 2009)

	CO	CH	NOX		CO	CH	NOX
<b>Beijing</b>	80	79	55	<b>Shanghai</b>	86	96	81
<b>Taiyuan</b>	50	50	40	<b>Guangzhou</b>	89	91	79
<b>Jinan</b>	70	60	40	<b>Chongqing</b>	86	37	86

Comparing to 1995, pollutants HC, CO and NOx respectively has increased 151%, 105%, and 201% from nationwide scale. Going by the present emission rate, by the year of 2010, both CO- and NOx emission volumes will increase by 200%, and the total share of vehicle emission will reach a level as high as 79% (SUMO, 2007).

#### 4.2.2 EMISSION FROM ELECTRICITY AND HEAT GENERATION

Between 1971 and 2007, the combined share of electricity and heat generation and transport jumped from one-half to two-thirds of global emissions.

Although coal only accounts for a quarter of the world's total primary energy supply in 2007, which accounted for 42% of the world's carbon dioxide emissions, because it re-release of heavy carbon content per unit of energy. Relative to natural gas, coal is almost twice the average level of emissions-intensive. If no additional measures, World Energy Outlook projects, coal supply will grow to 3184 million tons of oil equivalent (Mtoe) in 2,007 tons in 2030, 4887 million tons of oil.

Since 1990, electricity and heat production is the fastest growing sector, accounting for 50% of China's 2007 carbon dioxide emissions. There is rapid growth in the transport sector, but from much smaller base. World Energy Outlook projects, transport sector will continue to grow, will rise from 7% in energy demand in 2007 to 12% in 2030. China's demand for electricity is the biggest emissions driver. There was a peak capacity in 2006, but China still increase more than 90 GW in 2008, equivalent to the total installed capacity of Italy. Meanwhile, it closed nearly 17 GW small, inefficient coal-fired fossil fuel power plants about the size of Finland's electricity industry. Almost all (99%) of 1990-2007 emissions growth from electricity generation are caused from coal.

### 4.3 TRANSPORTATION DEVELOPMENT AND FORECAST OF CHINA

There is some dispute on the exact energy proportion of transport sector. While it is certain in recent years, the some researches show (CIRN, 2007), the energy consumption share of transport sector presently is at least higher than 10%, may be around 12% or so. In addition, 90% of energy expansion in the road transport sector is from oil, and fuel consumption is in the absence of precise official data.

Driven by rapid economic growth, improved living standards and sustained high urban population growth, the development of road transport has become a very pressing issue. By the end of 2007, civil cars vehicle reached 56.97 million and annual growth rate 19.8% of the annual stock after 2000.

**TABLE 7 EIA: TRANSPORT ENERGY CONSUMPTION BY MODE IN CHINA (UNIT: TCE)**

	2004	2010	2015	2020	2025	2030
<b>Waterways</b>	26.63	29.82	34.08	37.28	41.54	41.54
<b>Civil aviation</b>	10.65	23.42	29.82	41.54	52.19	71.36

<b>Railways</b>	22.37	34.08	41.54	47.93	59.64	71.36
<b>Highways</b>	101.18	134.20	172.54	225.80	297,16	382.37
<b>Total</b>	160.83	221.54	277.99	352.54	450.53	566.63

Table 8 summarizes a number of vehicle stock projections. According to the forecast, as shown in the table, the passenger car populations in 2030 are 227.89, 130.16-370.28 car, and 247-287 million. Li's (2005) forecast is based on the three economic growth (low, medium, high) and Wang's (2006) forecast is based on the diffusion rate of different vehicles. Taking into account the middle of the economic growth rate, projected population in 2030 is about 227.89-269 million cars. Some studies predict only concern passenger cars, for example, Li et al. (2005). In fact, there are many more other motor vehicles in China. Currently, in addition to about 57 million passenger car, there are about 98 million rural motorcycle and car. According to Shen (2006), Wang et al. (2006) predict, motorcycles, cars and rural vehicle population rise to 133 - 154 million in 2030 (2004).

**TABLE 8 PROJECTED VEHICLE POPULATION OF CHINA 2010–2030 (UNIT: MILLION)**

	Shen (2006)			Li et al. (2005)			Wang et al. (2006)		
	HWV	MC+RVa	LSb	SSc	HSd	LS	MS	HS	MC+RV
<b>2010</b>	49.28	92.93+20	44.66	52.02	58.55	52	52	53	77+40
<b>2020</b>	116.82	120.8+20	81.56	118.71	157.10	125	130	134	95+45
<b>2030</b>	227.89	133.83+20	130.16	239.86	370.28	247	269	287	92+41

a Motorcycles and rural vehicles ; b Low growth rate scenario ; c Middle growth rate scenario; d high growth rate scenario

In the current mode of motorization in China, there will be a tremendous increase in vehicle inventories and on-road vehicle fuel demand. By 2030, the total vehicle population might be 400 million (including 150 million motorcycles and rural vehicles), and the fuel demand 350 million tons (Hu et al., 2009). Meanwhile, with the gradual decline of domestic oil production, by 2030, total domestic oil production will not be able to meet half the demand of vehicles on the road.

China has a relatively low starting point though comparing to its rapid development. Resources constraints, rapid urbanization, large population base, economic transition and rapid developments, these constitute basic features of the new social and economic future of China. Rapidly changing environment imposes pressure on the government, enterprises as well as consumers. Pursuing short-term benefits, which is the natural response of most economic units even including the government, is very harmful to the long-term target of a sustainable road transportation energy

system (Hu et al., 2009). At the strategy level, the central government should provide stable, long-term, sustainable development guide as soon as possible. Such guidance should include alternative fuels and clean vehicles development, fuel economy and emissions standards, road traffic, especially urban transportation development, and vehicle consumption.

## CONCLUSIONS

From this Chapter on, Chapter 4, 5 and 6 will focus on the field of electric vehicle in the context of China based on multi level perspectives, respectively, landscape, regime and niche developments. Landscape factors may influence the dynamics at the regime and niche levels, as well as the possible interactions between them. That's why the goal of this step is to identify significant landscape features such as geo-political dimensions, related policies, as well as economic and environmental issues, where driving forces for this transition emerge.

In this chapter, to examine electric vehicles' development from a macro point of view, we have discussed respectively energy, environment and transport situation of China. Except for aggravating environmental problem, energy security is highly called for in China, considering its expanding oil consumption and shortage of oil reservation. In this case, alternative energy is needed to alleviate potential energy pressure. Electric vehicles provide an opportunity to transform the oil dependent transportation of China to electricity dependent. However, it is not optimistic from environmental point of view that peaking electricity demand will encourage using relatively abundant coals, which will intensify green house gas to a large extent.

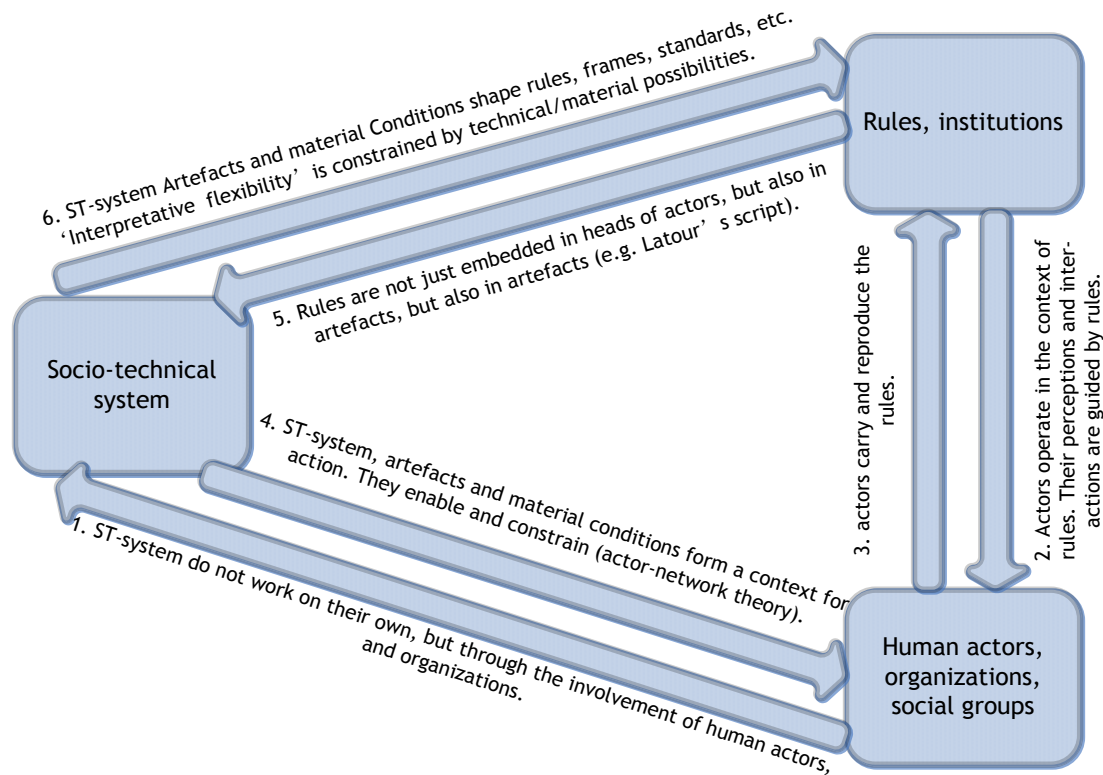
Pressing needs of solving environment and energy issues have been expressed from different aspects of China. No policy regarding to these problems is not an option for a sustainable future of China. Although difficulties are obviously seen in the big picture of China as a country being heavily populated, polluted, and fast developing. However, potentials are also shown in the study, especially in field of sustainable energy development. With tremendous effects of each factors in the study, an implication of huge difference between different socio-technical scenarios basing upon various options and directions are confirmed.



## 5 SOCIO-TECHNICAL REGIME OF ELECTRIC VEHICLE IN CHINA

After the case study of electric 2 wheels in China and exploration of China's broad context, we bring up the empirical question of the research again. *Who are the actors that possess significant influence in the transition of electric vehicle in China? And How do actors, interact in the present socio-technical system in China with respect to the case of EV's (and within the case of electric bikes and scooters)?*

According to the transition theory, it is the alignment in developments at the three levels that enables a shift in the existing regime to happen. When landscape factors put pressure on the existing regime, 'windows of opportunity' may open up, increasing like this the chance for radical innovations to break through. Therefore, a transition processes demands the analysis of the existing system as well as the understanding of how this system has been created in the recent past. This chapter thus tries to identify major characteristics and trends in the regime, including main actors, patterns and possible tensions that could provide linkages to niche developments.



**FIGURE 1 THREE INTERRELATED ANALYTIC DIMENSIONS (GEELS, 2004)**

In this chapter, we will focus on the most complex part of the multi-level perspective, socio-technical regime. First, I will briefly explain the three analytical dimensions (as it has been elaborated clearer in section 1.4), which is chosen as the angles I use to analyze interactions within the regime. After that, these three elements will be examined in turn regarding to the specific case of our study.

There are three dimensions (see Fig. 1), which form the basic dynamic structure of socio-technical regime, of which the automobile is part—the socio-technical system, actors, and rules that represent institutionalized behavioral patterns (Geels, 2004). This section will examine each of these elements in turn.

ST-system is linkages between elements necessary to fulfill societal functions (e.g. transport, communication, nutrition). As technology is a crucial element in modern societies to fulfill those functions, it makes sense to distinguish the production, distribution and use of technologies as sub-functions. To fulfill these sub-functions, the necessary elements can be characterized as resources. ST-systems thus consist of artefacts, knowledge, capital, labor, cultural meaning, etc (Geels, 2004).

Between sub-functions and resources on the one hand, and social groups on the other hand, the relationship between them are dynamic in nature. Actors' interaction (struggle, alliances, exercise power, negotiation, and cooperation within the limits of existing structures and opportunities) at the same time, they take action to adjust these systems. Another important point is that the structure not only constrains but also enables action. Social actors strategically and actively use, interpret and implement the rules of the system. They also creatively reform and rehabilitate them.

ST-systems are maintained and changed by activities of the actors, the same time, they formed an action context. Ongoing game and the action of the actor group result in changes of ST system as the impact of actors' move works.

Rules are not just linked within regimes, but also between regimes. ST-regimes can be understood as the 'deep-structure' or grammar of ST-systems, and are carried by the social groups. ST-regimes do not encompass the entirety of other regimes, but only refer to those rules, which are aligned to each other (Geels, 2004). It indicates that different regimes have relative autonomy on the one hand, but are interdependent on the other hand.

## 5.1 SOCIO-TECHNICAL SYSTEM

In this section, I try to map out socio-technical system, that is, linkages between elements necessary to fulfill transportation functions of EV in China.

The basic structure is referred to the diagram of Geels (2005) *the basic elements and resources of socio-technical systems*. The major adaptation here is to add a recycling process, which accomplish the life cycle of an EV. However, lacking of mass production of EV leaves us little after-use information and statistics to take a further look at this link (Matheys, Van Autenboer, 2007).

From the left side to the right side of this diagram (or upper part to lower part) in figure 12 are sub-functions respectively production, distribution, domain of use and recycling process. To fulfill these sub-functions, the necessary elements can be characterized as resources. ST-systems thus consist of artefacts, knowledge, capital, labor, cultural meaning, etc.

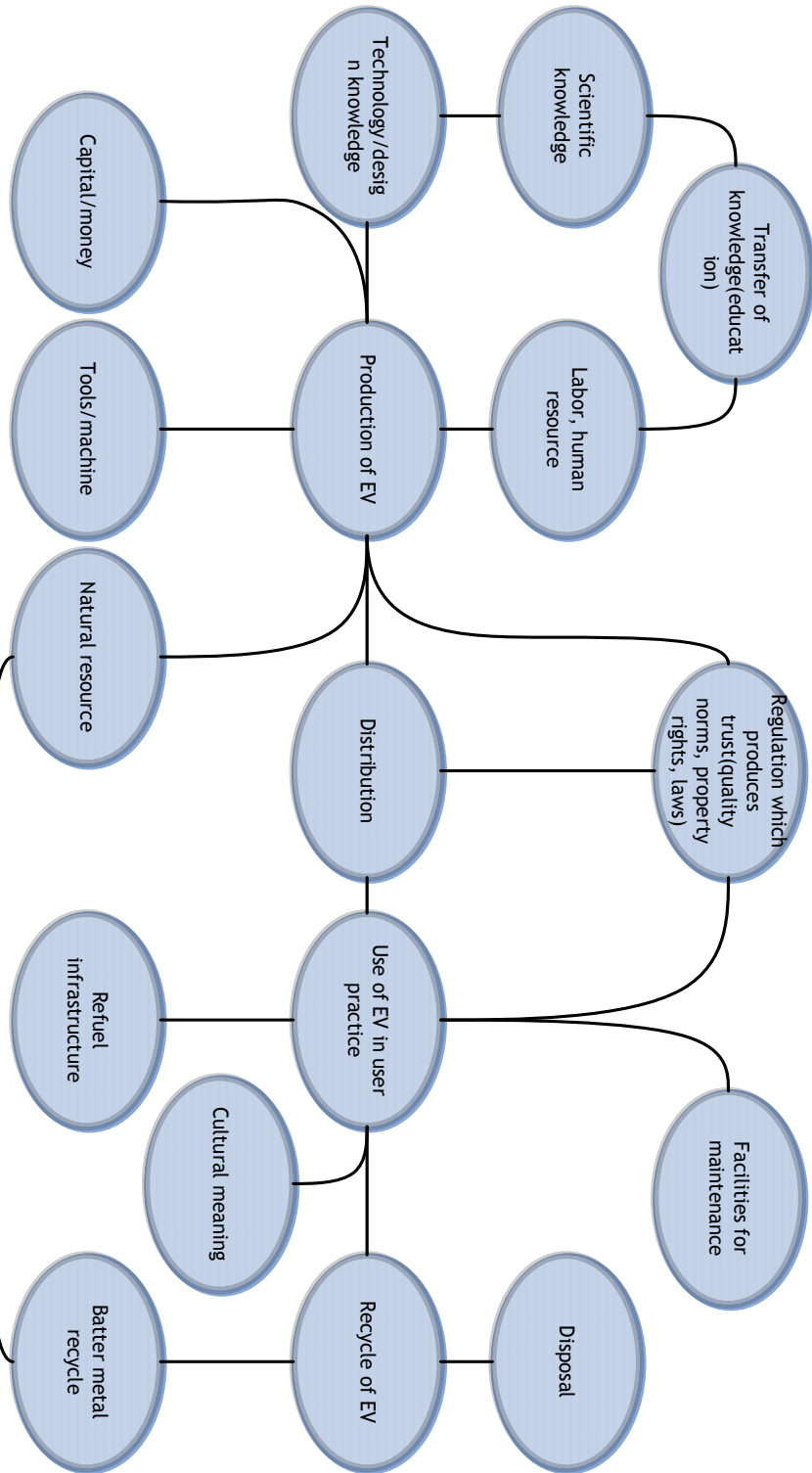
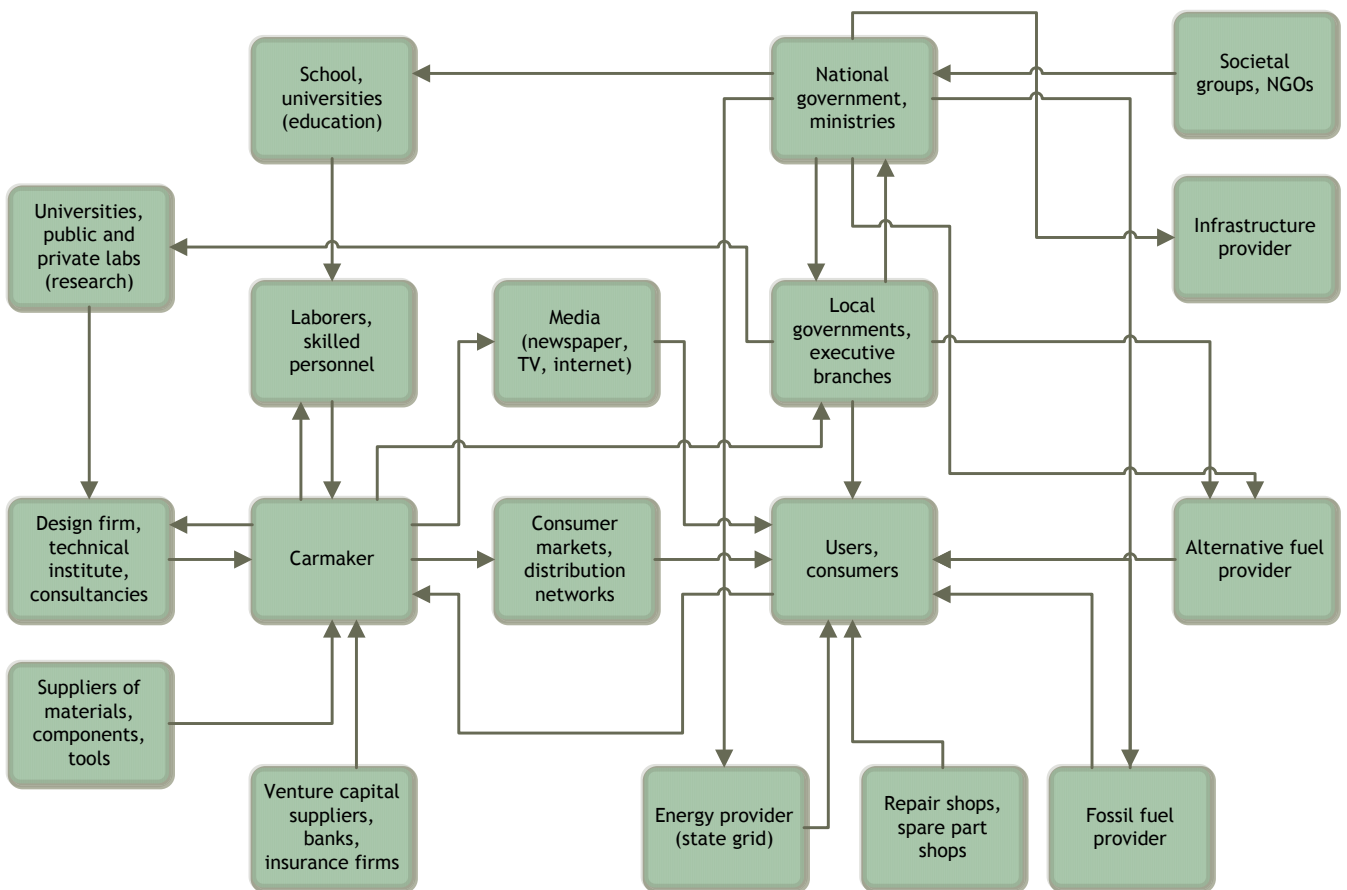


FIGURE 12 SOCIO-TECHNICAL SYSTEM OF EV BASED TRANSPORTATION

## 5.2 ACTORS AND SOCIAL GROUPS

Socio-technical systems do not function autonomously, but are the outcome of the activities of human actors (Geels, 2004). In this section, the network of actors and social groups at stake regarding to our case is mapped out based on the socio-technical system, which is identified in the previous section. This network serves two purposes, one is to gain more insights into driving forces behind this dynamic system, the other is to locate the crucial relationship in this network, at which we may have a closer look in the following section.



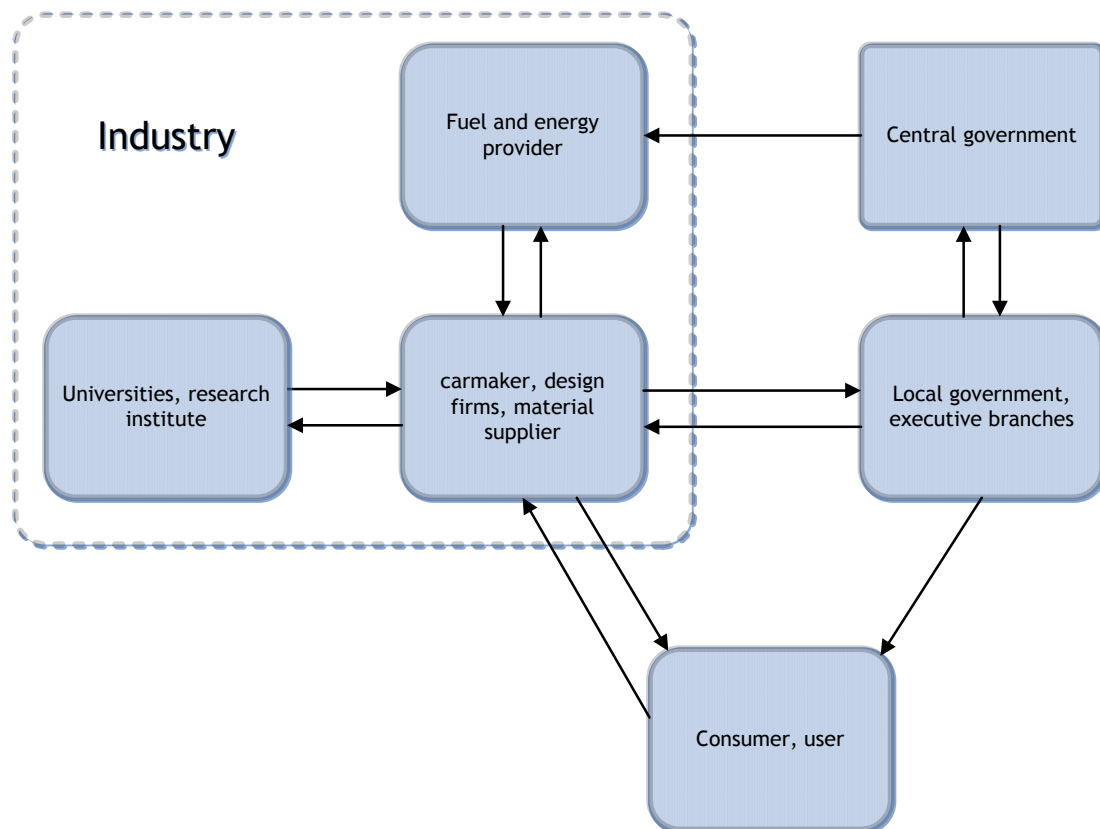
**FIGURE 13 SOCIAL GROUPS WHICH CARRY AND REPRODUCE ST-SYSTEMS.**

The left side of this network in Fig. 13 is mainly a reproduce of the social-technical system in Fig. 8. However, regulations in this network have to be further differentiated. According to the case study of E-bike in Chapter 3, diverse policies made by different levels of authorities have to be analyzed, which tend to produce various effects depending on the combination of regulations.

Mostly importantly, central government and local governments have to be differentiated and treated individually. Certain industries as oil providers are directly under control of central government, and so as refueling infrastructure, which are either state owned or belonged to state-owned enterprises. Electricity supplier is also a state-owned enterprise called State Grid. Basing on the facts above, the most likely owner of fuel provider of FCV is also the state, it is not a wild guess concerning 'control'

has always been high on the priority list of the central government, especially comes to the potential crucial points of the country's well being.

Local governments are not simply subordinated organization under control of the central government, which is also shown in the case study of E-bike. They have their own power range especially comes to the relationship with various industries. And different local government have different preference for supporting industries, it can be based on their natural resources of the region, condition of infrastructure (e.g. railway network), historical behavior pattern, etc. For example, on March 25, Nissan-Renault alliance has signed a further agreement with the Wuhan municipal government on the promotion of the electric vehicles. According to the agreement, the two sides will start the market research for the promotion of 25 sets of Nissan electric cars in Wuhan in 2011. For this reason, the Wuhan municipal government has planned to build 250 charging devices in the next two years to ensure a successful operation (Zheng, 2010).



**FIGURE 14 NETWORK OF GOVERNMENT, USERS AND INDUSTRY.**

To zoom in to the complex interrelations of governments, industry and users, we will have a more articulated network (see Fig. 14). In this diagram, the relationship of carmaker and local government on the one hand, carmaker and users on the other hand are more subtle and unpredictable, since

they are not completely under control and coincide with anticipation of the central government. Dynamic nature of market mechanism can play a key role in these relations.

For local government, they have different problem agenda, which can influence willingness of implementation and the way of interpretation of certain centrally announced regulations. This will either offset or promote this policy in question to a large extent. For users, they have free will to choose what to purchase or not under the giving context. Under the circumstances of EV introduction, it is a question indeed, since a large part of decision making power is in the hand of the demand side (users), not in the production side or the regulation making side. For industry, as a vital link between the two, is probably the most active role in this game. It has to fast react to any actions made by the others, while concerning competitiveness within this industry. Neglecting novelties or misinterpreting policy and market reaction can be fatal to the development of the organizations.

Human actors are embedded in social groups which share certain characteristics. These social groups have relative autonomy. Each social group has its distinctive features. Members share particular perceptions, problem-agendas, norms, preferences, etc. It is no wonder that these three social groups have different sometimes conflicting interests. How they are going to act and react in this network in order to reproduce socio-technical system, is very important to find out in the further analysis.

## 5.3 RULES

In this section, two relationships identified in the previous section are further explored.

### 5.3.1 CARMAKER-CONSUMER RELATIONSHIP

In the exchange of consumers and car manufacturers display some typical behavior patterns, it has been institutionalized. These patterns can be categorized as regulative, normative and cognitive rules. The following sections describe the three relationship patterns of behavior between car manufacturers and consumers. Knowledge, attitudes and expectations in this relationship played an important role.

#### 5.3.1.1 PUBLIC ACCEPTANCE (NORMATIVE RULE)

This analysis is based an interview conducted among the general public audience of *2010 Beijing international automotive exhibition*. The Expo, with a theme of "Imagining the Green Future" this year, will focus on clean energy vehicles with 95 new-energy-driven cars from foreign and Chinese automakers on display. The biennial auto show is open to the professional public from April 25 to 26 after opening exclusively to journalists in the past two days. It will open to the general public from April 27 through May 2. China made 13.79 million cars in 2009 while sales hit 13.64 million vehicles in the domestic market, up by over 40 percent year on year. Since China has already become the world's largest auto market, it would be difficult for global auto makers to progress without a clear strategy for the Chinese market. New energy vehicles and the latest energy-saving technologies were brought to show.

The basic structure of this interview is based on the analysis by R.R. Heffner et al. in 2007, *Symbolism in California's early market for hybrid electric vehicles*. This study explores the symbolic meanings being created, appropriated, and communicated by the owners of hybrid electric vehicles basing on qualitative interviews. With an adaptation to China's situation, that few HEV or EV adopters can be found, the interviewees in this analysis would be potential auto buyers with various interests, and this exhibition would be a good opportunities to find them. 18 feedbacks are collected, and two of them are chosen to display in this section, since they are relatively complete and basically represent almost all the key points of the 18 interviews. Detailed questionnaire and interview in full length can be found the Appendix.

### INTERVIEW METHOD

The questionnaire is revolving with the questions below:

1. Household vehicle history: A description of past and current household vehicles, vehicle use patterns and household life stages, who uses the vehicle, how far and where the vehicle is driven.
2. Purchase narrative: A narrative of the HEV purchase told by the interviewee with limited prompting by researchers. Levels of different expectation concerning their future purchase plan are explored.
3. HEV benefits and disadvantages, stated tolerance exercise: Particularly in the evaluation of EV benefits and disadvantages. Participants identify their perceived or expected advantages to buying an EV, and explain the importance of these advantages in their own possible EV purchase.
4. Prerequisite: Interviewers propose replacing the household's car with another vehicle, and interviewee discusses the conditions and prerequisite for them to consider purchasing an EV.
5. Symbolic meaning assessment: A series of questions and exercises designed to assist participants to verbalize symbolic meanings. For example, participants are asked to define a stereotypical EV buyer and what they themselves say about their EV to strangers and friends if they buy one.

### INTERVIEWS

The exhibition giving the impression as a whole that the innovative and the conventional were together all along the way, however, conventional cars still capture more focus. Big carmakers such as BMW, Mercedes, Nissan all have launched electric vehicles (HEV, BEV), but they are still far from mass production.

Some more brands still do not have electric vehicle of any form, their major products are still new module cars or upgraded old version. Coincidentally, electric vehicle did not draw too much attention from the audience, and even less with interests for purchase. BYD booth was the most popular among all the other EV display, because the main introduction of BYD this time is focus on EV, it will attract more or less a part of the audience, but the situation as a whole is not very optimistic. This description might be slightly different with what one can find on the news, the possible reason for

that is the separate periods of the exhibition. Since the professionals and journalists who participated mainly in the first period might have focused more on the 'green' theme and relating cutting edge technology. While our interviewees are still the general public, and so is our focus.

Looking at the various booths, most contracted cars are medium or large size jeep, it might have something to do with favorability of both carmaker and consumers. However, Mercedes-Benz's smart has a unexpected rise, attracting a large amount of audience.

There was not a lot of EV on display. Quoting from the Toyota sales staff is that, if an electric car goes into real life, its battery life will trouble the owner a lot, with today's technology level, the battery's charging capacity will decrease significantly after one year, to replace the battery the cost is not low. Without doubt, electric vehicle is not ready for practical use at this moment, the purpose of displaying it is to show the carmakers' R&D strength that is ready to get into this field.

Two interviews are chosen to be displayed as following, since they are relatively complete and basically represent almost all the key points of the 15 interviews.

*Personal Information: Age 20-30; Gender: Male; Occupation: young professionals*

*My family had no vehicle. Subway is usually the main public transport to work, though I take taxi occasionally. Every day I have to travel around 50KM mileage. I have plan for purchasing a car in recent years, budge within 100-200 thousand RMB (10-20 thousand euro), mainly used for daily commuting and holidays short distance travelling. Because I would like to drive for travelling, so it is necessary to buy a sports car, which can provide sufficient range and power. Carmakers from Europe and the US have more models of this kind, and provide relatively higher quality, I will first consider these brands. The theme of Beijing Auto Show this year is green, which many manufacturers dominated the exhibition with the economical and environment friendly new launched models, which played a good slogan. Electric vehicles for me, is a relatively new concept for me, and from the introduction I can get no more infos than a couple of numbers. For example, Mileage, maximum speed, charging time, etc. But what I most concerned about is the car's price, levels of convenience, and the so-called economical and environmental friendly characteristics, which is always mentioned. For these issues I haven't got a better understanding this time. And for a*



*innovative car, the related facilities would be not completely perfect, especially the pure for electric car, which will greatly limit the range of the vehicle. I heard the price of these cars are more expensive than conventional cars of the same level even after the possible subsidies, from economic considerations it is not the right car for me at present. If I have plan for buying a second vehicle in the future, then I will consider this type of vehicle. I think only when a person who has a definite purpose for using these kind of vehicle or planning for a second vehicle that he or she would like to consider of it , at least they can have more flexibility while using.*

*Personal Information: Age 23; Gender: Male; Occupation: College Students*

*We have a Chrysler Jeep at home, we use it regardless of holidays or for everyday use, it is already an integral part of our family. After graduating from college I intend to buy a car for my own user, I am not sure about the budge, it should probably be around 200.000RMB (20.000Euro). As I have witnessed the radical surge of vehicles in recent years, and travelling in the urban area sometimes no faster than a snail , besides it also burn more fuels when it travels like that. Therefore I intend to buy a smaller car, it is economic and very environmentally friendly, after all, it does not require too much while satisfying basic needs. I don't have particular requirements for the car's outlook, but the quality must be guaranteed. I don't have specially favored brand in mind, I guess I will just choose then, I will listen to what others say about it. This year's Beijing Auto Show has green as the theme, and the major automakers have introduced their own various electric vehicles. Before this I always see the information of electric vehicles on internet, so I expect to see what they will introduce this time. I think if you buy electric vehicles, the most important thing in it is to support the nation though your own action and environmental preservation, after all, now that China is too dependent on oil, while with more*

*availability with electricity power, if we actively use electric cars, I think it will be a great help for the nation's development. And environmental preservation, then, after all, using electric power plants to generate electricity is also another way of energy driven, it is hard to say which one is more environmental friendly in the short term. And the performance of electric vehicles from the manufacturer's description, I think there is no problem that the performance of electric vehicles to meet the daily driving needs, because a top speed of 100KM, Mileage 150KM, fast charge less than an hour, which is sufficient for the normal sized city of present and urban road conditions, even the number of refueling station is scarce right now. So if the price is not particularly outrageous, I will choose electric cars. BYD has a good model this time. If someone around me buying a electric vehicle, I suppose they are more or less doing that to support the national policy or to protect the environment, after all, it is not very popular now, its advantages are not obvious, and in some aspects it is far from the league of conventional cars. If I buy it, and tell others about my car, I guess it will require some explanation, after all, the meaning behind it is larger than its practical concern.*

## CONCLUSION

Although individual preferences are diverse in the interviews, some general points shared by almost all the participants also emerge, especially in comparison with the results of the previous interviews in the US by R.R. Heffner et al., which is shown in Chapter 3. These points are categorized as following:

### ECONOMICAL CONCERN

Almost all the participants have concerns for economical issues of EV. However, not much attention have been paid to fuel price, one possible reason for that is the relatively stable fuel price in China, which the government have maintained through policy measures (e.g. subsidies, tax reduction). And concerns for this issue is not limited to the initial purchase price, maintenance fee and overall cost of EV are also considered to a large extent. And the next surge of auto purchase is also expected to be comprised by the urban young white-collars, whose preferences have to be within their economical limits.

### PREFERRING MATURE PRODUCT

This expectation is expressed by most antcipants that the products have to be mature in technology application, infrastructure, maintenance, etc. And some of them mentioned carmakers with higher

reputation are favorable, since they are more likely contributing to the maturity level of the product, which is ready to use and easy to fix.

#### **EASIER INFLUENCED BY PEOPLE AROUND**

Many participants mentioned that if people around them have purchased or consider buying an EV, it will significantly influence their choice of vehicle. The current condition is that not much advertisement or demonstrations are going on around the general public, and they know relatively little about EV or HEV. Other than concerns for a more reliable vehicle, this might well have come from collectivism as a cultural pattern. Some young people have mentioned their need to express themselves as individuals, however, most people preferred a conventional looking car for everyday use. They don't want to be 'too different'.

#### **FLEXIBLE MOBILITY NEED**

Vehicles should be able to satisfy any mobility need one household might have, and for most households in China, that is one car for all. Most potential purchasers have plan for only one car, and it has to satisfy their need for various distances (e.g. occasional travel). And usually it is not that one car serve the need for one person, but the entire family. Thus the capable range of the car has to be flexible.

#### **INCREASING CONCERN FOR FUEL EFFICIENCY**

Some participants have concerns for increasing fossil fuel price recent years, as a result, higher fuel efficiency is more and more being considered as an important criteria when purchasing vehicles. It is not a surprising phenomenon giving the context that the domestic fuel price is becoming more susceptible to the dynamic international market. This is due to the governments' newly issued regulations, e.g. 'fuel tax reform' in 2009.

#### **5.3.1.2 CONSUMER TYPE (COGNITIVE, REGULATIVE RULE)**

To accomplish large scale introduction of EV, acceptance of the general public is inevitable. However, at the initial stage of this transition, various modes of application of EV should be explored, which might have an even larger proportion of practical use than the general public. And this is a recommendable process since it is able to provide a period for improving the infrastructure it requires, while at the same time gaining more public acceptance. Public sectors and public transportation system are the ideal consumers for this stage, since they do not have as much economical concern as the general public or private sectors. And some cities have already moved in this direction.

Beijing government has plans for action, at present, the first batch of a total of 50 pure electric buses are already running, while the pilot charging stations established for this purpose have also begun operation. In addition, Beijing Municipal Science & Technology Commission has begun to study how to charge electric vehicles like taxis and passenger cars in fixed charging stations. Next, Beijing will consider forming an electric taxi team traveling within the Fifth Ring Road, and setting up charging

stations especially for taxis. If the pilot station works well Beijing may promote electric passenger cars and set up a group of charging stations for pure electric cars and hybrid electric vehicles [34].

In accordance with EV introduction plan, Shenzhen City, strives to promote using of EV in transit, highways, and family car all together, hopefully a total number of 24,000 alternative fuel vehicles would be in use by 2010. Among them, 4000 is expected to be hybrid and pure electric bus, 2500 for dual-mode electric taxi, 2500 for official dual-mode electric vehicle, 15000 for dual-mode electric car. At present, Shenzhen has opened three demonstration lines for new energy sources bus, 146 hybrid buses and 10 electric taxis in operation; public departments has 20 dual-mode electric cars in use. With all kinds of alternative fuel vehicles in use, construction of supporting infrastructure is also expected to be accomplished gradually. In accordance with the planning of the Shenzhen Municipal Government, 2012, Shenzhen will build all kinds of electric vehicles charging station (post) 12 750. Among them, there will be 25 for each of fast and slow charging stations for bus, charging post 2500 for official cars, 10000 for public slow charging post, and 200 for public fast charging station (People's Daily, 2010).

Government can play actively as a pilot role in this game. Owing to the objective phenomena that the price of the new generation of fuel cell powertrain system is rather high in the phase of demonstration and the recognition degree of the public is low, the government can lease or purchase the vehicle and officials take the lead in trial driving (Wang, Ouyang, 2007). The same goes with public transportation e.g. bus and taxi, since they have more routinely travelling routes, it is easier for the first batches of infrastructure to be launched.

#### 5.3.1.3 IMPROVING PROCESS (COGNITIVE RULE)

Ever improving preferences for cars are enabled by consumer expectations and car manufacturers' drive to increase profitability. The number and variety of automobile models available is overwhelming. Consumers are unable to make a detailed assessment of all models. In such settings, a two-stage decision process is typical (Ben-Akiva et al., 1997), and the car market is no exception (Lane, Potter, 2007). In the first stage, consumers narrow down the range of vehicles they consider fit to a manageable number, using a few 'primary' criteria. The models in the narrowed-down choice set can be assessed in more detail, using a more extensive set of 'secondary' criteria (Thomas, 2009). The final choice results from this detailed trade-off.

Assuming innovations such as FCVs and BEVs, for which consumers' awareness is similar to that of HEV, a continuing trend, complicating the introduction. A vast various types of models have been provided in few decades. In the terminology of MacDuffie et al., this corresponds with fundamental variety, implying that the variety of products is larger. Different versions, such as motorizations, of these models are increasing, so are peripheral varieties, they are rising too. This fragmentation of the car market makes it hard for new technologies to penetrate the market, since they will necessarily start out with a smaller variety of models (van Bree, et al., 2010). Furthermore, shift in preference of

consumers and competition of carmakers drives to improvement in design and production. Cars are getting better in almost all aspects. Such as reliability, safety, comfort, which are important attributes that consumers' expectation keep rising, and carmakers have to reach these expectation in order to keep their market share.

Manufacturers clearly recognize that to expand its product line, and profitable, with the basis of their production system is inconsistent. A major factor driving the car industry development and rapid diffusion in the early 20th century is the mass production process, which basically only allows production of one version of a single model. Improvements to the design and production process to make it 'lean' have made it possible to produce more variety. Part of lean production has been to organize suppliers into functional tiers, with suppliers in first tiers being given full responsibility for design and production of particular modules (van Bree, et al., 2010). Driven by the needs of car manufacturers to reduce costs, they have developed a number of modules outsourcing and production processes, vendors, a trend that is expected to continue. Therefore, relative contribution of the change of the value chain is possible from the car manufacturers to suppliers. More modular design and production are thought to speed up innovation rates (Baldwin, Clark, 1997). This is plausible, because modular design reduces the complexity of improving individual modules (Pil, Cohen, 2006). In addition, the automaker's R & D efforts have spread in many areas with the attempt to innovation, while suppliers can focus on their expertise more easily and work with experiment of the radical innovation.

### 5.3.2 LOCAL GOVERNMENT-INDUSTRY RELATIONSHIP

Not like structure provided by B. van Bree et al. (2010), there is a direct link from user to government through voting process, this influence in China is more subtle and circuitous, due to the political structure. Carmaker in this diagram is heavily influenced by both user and local government, it is an intermediate group, and so does local government. There is few actor can influence decision making of central government, however, local government as the closest link to the market, functions as a crucial link to the national government. Furthermore, based on conclusions I have drawn from the case of e-bike, local government is the key role in its large scale introduction. Relationship between industry and local government is well worth researching.

Institutions at the local level will often determine the success or failure of development efforts (Segal, Thun, 2001). Local government as the intermediate between many elements (user, carmaker, central government), is crucial to transition of EV. Thus a local government-carmaker or local government-industry analysis will help a lot to identify dynamic trends of scenarios.

Economic reform in China produced a similar mosaic effect. The central government expanded both the decision-making authority of local governments and enterprises and their ability to retain the revenue earned within their respective jurisdictions (Shirk, 1993). This ultimately result in more

power for local authorities to exercise their power to promote local development, sometimes even by issuing local regulations ignoring national objectives.

#### 5.3.2.1 HORIZONTAL PATTERN—VERTICAL PATTERN (COGNITIVE RULES)

Local governments tend to hold different attitudes and rules towards different industries, which can be reflected in the 'pillar' industry they engaged in promoting and the structure of these industry. As Gary Herrigel writes with respect to Germany, "different groups of industrial actors . . . will invariably conceptualize, organize, and enact industrial activity in ways that reflect their own pasts." (Herrigel, 1996). These differences can be seen as a way been derived from a region's past. And they play an important role in determining whether new markets consist of large or small enterprises, vertical or horizontal relations, and interventionist or more flexible government regulations (Segal, Thun, 2001). In Shanghai, the local leaders have both the desire and ability to act like a state of development at the local level. In the pre-reform era, firms in cities have been more closely controlled by municipal officials than urban enterprises in Beijing, these officials used to be involved in companies in every way of operation, and they have bureaucratic tools to do so. Policy makers preferred to have large state-owned enterprises dominate new markets and actively intervened to coordinate the vertical relations between the highly integrated units (Segal, Thun, 2001). In contrast, local leaders in Beijing, often do not have bureaucratic authority or funds to support large conglomerates, so they have to engage in promoting horizontal structure of production and research institutions. After 10 years of development, Shanghai Volkswagen was sourcing 88 to 90 percent of domestically sourced parts within the municipality of Shanghai, while Beijing Jeep could only source 20 to 30 percent of its components from within Beijing (Thun, 1999).

Sectors are those subsets of the economy that involve a combination of highly complementary activities (tasks, services, goods, etc.) that must operate in coordination to produce a certain end product (Kitschelt, 1991; Hollingsworth et al., 1994). The concept is similar to the system, but better than big. As companies in the same industry usually solve similar problems and are more likely to adopt the same production process for control of development within and outside the firms, a comparable way of allocation of resources and information.

In the automotive industry, a large number of capital investments of assembly plants and supply vendors are required at a early stage, and the sector structure must be conducive to the development process of a well established manufacturing technology. Hierarchical corporate structures were useful not only for easing asset specificity and facilitating a coordinated investment approach (Segal, Thun, 2001). In the automotive industry, for example, company managers often rely on the head office of their corporation. This is another part of the learning process within the automotive industry development functions. In more technology driving sectors, such as information technology, innovation and enterprise creation requires a very different approach to development. Companies need the technology, talent and capital (although not as quick as in the automotive industry, nor in a coordinated manner), they also need a regulatory framework that encourages innovation and formal

and informal inter-company networks. An industry with a horizontal structure will move toward vertical integration when technical advances in one part of a manufacturing chain give market power to a firm making a particular subsystem because market power in the one subsystem encourages bundling with other subsystems and movement toward an integral engineering solution (so as to add value and increase control over the final product) (Segal, Thun, 2001). The result is likely to be an encouragement for vertical integration. In the opposite direction, competition from niche competitors, and many technical challenges and dynamic advancement of the market, disintegration of rigid structure in vertically integrated large enterprise organizations take place.

R&D for electric vehicle is somewhat a combination of these two forms of organization. First, research for FCV and BEV can be categorized as cutting edge technology, which has large room for improvement and is not ready to consolidate to a bureaucratic form. On the other hand, this technology is based on conventional electrical motor system and auto design, to some extent, a technology for upgrading auto, in the end, is still an auto. And conventional auto industry is being constantly considered to be the one to carry this out, and maybe also the only one who is capable of conducting such a technology-required and capital consumed activity.

For the development of the automotive sector, government services may be more interventionist in the initial stage of growth and include the provision of investment capital, coordination of the localization process, and the monitoring of technology transfer (Segal, Thun, 2001). The highlight is on encouragement of leaning instead of innovation.

#### 5.3.2.2 COMPETITIVENESS BETWEEN LOCAL GOVERNMENTS (NORMATIVE RULE)

Currently, high-tech companies, that have set up in Beijing are to start factories and branch offices in Guangzhou, Shenzhen. In these cities, local governments are also actively soliciting such enterprises, and to provide more advanced venture capital approaches and the ability to list on technology stock markets as incentives.

This competitiveness exists among local government to attract foreign investors, which could result in increase in tax revenue, working opportunities, most importantly technology transfer.

Case studies of the three main Sino-US passenger-car joint ventures reveal that little energy or environmental-technology leapfrogging has occurred in the Chinese automobile industry as the result of the introduction of US automotive technology (Gallagher, 2006). The specific data is shown in Table 9. The main reason for cleaner, more energy efficient is not to be transferred is that simply no compelling policy incentives for U.S. companies to do so, better transfer of technology from foreign companies is not to happen voluntarily.

Why is that? Identified by Kelly Sims Gallagher (2006), a vicious circle exists in government and industry. In this vicious circle, the Chinese government is reluctant to pass more aggressive emission control regulations for fear that the Chinese companies cannot meet them, which could cause those

firms to go out of business. Local government follows this policy routine on the one hand to protect their own local firms from bankruptcy. On the other hand, sticking to strict rules on restricting foreign firms may push them to more policy favored province or city, which is certainly not a desirable outcome. Another reason for this situation is that China's refineries are not currently outfitted to reduce the sulfur levels of imported crude. The resulting sulfur level of refined gasoline available in China is currently about 800 ppm for gasoline.

**TABLE 9 FUEL ECONOMY COMPARISON BETWEEN CHINESE AND US MODELS (GALLAGHER, 2006)**

Model	Fuel efficiency in Chinese model in urban driving (mpg)	Fuel efficiency in the US or European equivalent model for urban driving (mpg)
Buick new century	18-21	20
Buick sail	23-26	27.2
Jeep Grand Cherokee	14	14
Jeep Cherokee	18-21	16
Jeep BJ 2020	17	No equivalent
Ford Fiesta	32	26

There are two ways to break the vicious circle. One is to improve domestic technological capabilities for these cleaner technologies within the Chinese firms (Gan, 2003). This is what China's Ministry of Science and Technology (MOST) is trying to do with the '863' high-tech research programs in clean vehicles. Another way to break the vicious circle is simply to issue regulations for Chinese government and local governments, while accepting some of China's domestic companies may have to suffer.

### 5.3.2.3 MOTIVATIONS FOR FOREIGN R&D (NORMATIVE RULES)

A strong driver for foreign R&D is the market. If the company's business requires local product adaptation and intensive customer cooperation, it is likely that local development units will be established (e.g., von Zedtwitz and Gassmann, 2002, p. 580).

For international companies, there are several reasons to carry out local development (Gallagher, 2006). First, with new models continually being introduced into the Chinese car market, it will be vital to keep their product development in line with model releases from different car manufacturers. In order to respond quickly to customer needs in the future, it is not enough, through the R&D sector development activities of the head quarter. Second, there are cost saving potentials due to low engineering man-hour cost in china. Cost savings can be achieved from the products developed abroad, (e.g. Germany) and sometimes which are over-designed for meeting comparatively lower



local customers needs. Third, engineering support to local customers will be easier to follow up on than with a central R&D department. Fourth, due to specific local conditions in which automotive products are operating, some of the development activities must be conducted on-site. Examples of such activities include the localization and climatic conditions and quality requirements and development of natural gas in the power train adjustments. In addition, the infotainment service needs to be localized with cultural and linguistic adjustment.

In the automotive industry in China's cooperation will be primarily to reduce the development time and take advantage of joint use of the resources and facilities, regional market knowledge, and market barriers to entry creation.

In our case there are two kinds of potential cooperation partners: universities and automotive companies along the supply chain. In the Siemens VDO case, universities are preferable cooperation partners primarily for two reasons: first, the contact with a university will be seen as a good source of qualified automotive engineers. Second, universities might possess testing facilities crucial for product development, such as an engine test (Gallagher, 2006).

China's policy makers believe that an effective way to eliminate the international technology gap is to strengthen the links with international R&D community. One important means is the establishment of high-tech parks combined with incentives such as free rent, low tenancy costs, favorable lease terms, and tax relief. As identified by Ambrcht (2002), there are several multi-faceted reasons behind these kinds of policies. Foreign laboratory will bring capital investment, ancillary expenditures and employment opportunities. In addition, they also help attracting back outstanding ethnic Chinese experts from around the world to conduct advanced research.

#### 5.3.2.4 BARRIERS FOR FOREIGN R&D COOPERATION (REGULATORY, NORMATIVE RULES)

##### BUREAUCRACY

As has mentioned above, the Chinese Government have been encouraging foreign R&D activities in China. According to some interviews of R&D management experience (Gallagher, 2006), receiving tax reduction and other incentives on favorable terms can be a distressed and long-term process, because of various bureaucratic obstacles and very specific rules. To import test materials can be difficult (IBM), the transfer of people from Beijing to Shanghai needs an official permit (require long-term preparation, Siemens, ABB).

##### UNCERTAINTY IN LEGAL CHANGES

As the lack of transparency in decision-making in China, China's industrial political, legal, technology policy and strategy is difficult to discern. This provides more uncertainty for foreign R & D activities in China. For example, in industry standards and regulations in the automotive industry China treat Europe as a role model. Therefore, the Chinese government's ambitious follow Europe (such as automotive norms, emission standards (EURO 3, 4), the obligations of airbags, tire pressure control

braking power control). The effectiveness of automobile and other product standards will be left to the discretion of the government. The unpredictability of this type of research and development will be very challenging.

#### INTELLECTUAL PROPERTY RIGHTS

As the challenging nature of China's economy, foreign companies have to assume some unintentional technology transfer. As Schumpeter noted, innovations should lead to temporary monopolistic profits in order to harvest previous R&D investments. China has made progress in IPR protection and has ratified various international treaties and conventions, to show the world its efforts to international intellectual property standards to be in step, but intellectual property (IP) piracy is still rampant in China.

#### IMMATURE LOCAL MARKET AND HUMAN FORCE

At this stage number of products developed in the local is still not sufficient to achieve adequate economies of scale. One major reason is the crowded car market in China. About 2,400 companies are involved in the automobile industry. At present there are 120 complete vehicle plants, of which 12 have a yearly output exceeding 10,000 units, and only three have a production capacity exceeding 300,000. According to industry experts, an enterprise with an annual output of less than one million is not competitive in the international market (Gallagher, 2006). A further dilemma, which is a research and development manager for car industry in China are generally concerned as lack of experience automotive experts. Although there are several universities in China with automotive departments, with the increasing need for automotive experts, number of qualified automotive engineers is still insufficient comparing to international standards.

### CONCLUSIONS

In this chapter regime level of MLP (multi-level perspective) model is closely look into. Actors in figure 13 are shown as essential stakeholders in this analysis, where local government-carmaker relationship and carmaker-consumer relationship are examined closely. This is also one of the results of the case study of e-bike's development in China, and these actors are also actively involved in that particular case.

Through socio-technical system, a general picture is depicted for electric vehicles' regime. And the corresponding social group network emphasize on activities and influence of each actors. A group of key actors emerge from the general picture, and some interrelations of them are further elaborated. Carmaker-consumer relationship and local government-industry relationship are analyzed through several characteristics, which constitute important factors of socio-technical scenarios of this study. On the other hand, these major characteristics and trends in the regime could provide linkages to niche developments.

For local government, its administration pattern towards industries have been classified as horizontal and vertical pattern, Beijing and Shanghai are illustrated as representatives respectively. At the same time, competitiveness between local governments exist which actively influence the way they deal with different industries. For auto industry, especially international carmakers, barriers and motivations are ruled out. Market pressure and legal obstacles push and pull automakers' position and attitudes constantly, which result in a dynamic situation.

For consumers, an interview is made to evaluate the public's attitudes towards conventional vehicle and electric vehicle. Although the number of subjects is not enough to draw significant conclusion on electric vehicles' public acceptance, some general characteristics can be obvious observed as foundation especially comparing to another interview conducted in the US. For carmakers, intensive competition of the auto market has formulated a series of cognitive rules to follow in model varieties, expansion of production lines and incremental improvements.

## 6 NICHE DEVELOPMENT OF ELECTRIC VEHICLE IN CHINA

Except from the institutional obstacle, e.g. energy structure, lack of infrastructure, the ones being mentioned most in the development of electric vehicle are technical constraints. It is important to have a close look at the EV itself, and explore the state of the art in this field.

Generally speaking, EV can be categorized into three groups, battery electric vehicle (BEV), fuel cell electric vehicle (FCV), hybrid electric vehicle (HEV). And more categories can be drawn from different fuel for fuel cell, different material used for battery, and obviously more combination between them or conventional fuel. There are currently various barriers to the wide spread adoption of both BEVs and FCEVs; the most important being technical, economic and infrastructural.

For BEVs technical barriers are mostly associated with battery technology (Tollefson, 2008). What are the most promising materials and technology for EV's battery making to improve its performance? What are the environmental consequences for these different materials? And what is the distribution of this material around the world?

For FCVs, problem of infrastructure scarcity is prominent, since its wide introduction strongly depends on availability of complementary goods (e.g. refueling station). Besides that, different fuel chains of FCV have different environmental and economical performances, among them which are the best for China taking its natural resources distribution into account?

For HEVs, is any combination of different technology will bring optimal benefits to this transition? And will this compromise also reduce the ultimate achievements we can expect from electric vehicles?

When niche developments together with landscape factors put pressure on the existing regime, 'windows of opportunity' may open up, increasing like this the chance for radical innovations to break through. The objective of this chapter is to describe the technological niches, including the recent dynamics, current status and future potentials. It includes alternative technological forms, the possible markets, a brief history of the niche, costs, barriers, user preferences, policies, dimensions concerning market, production and infrastructure.

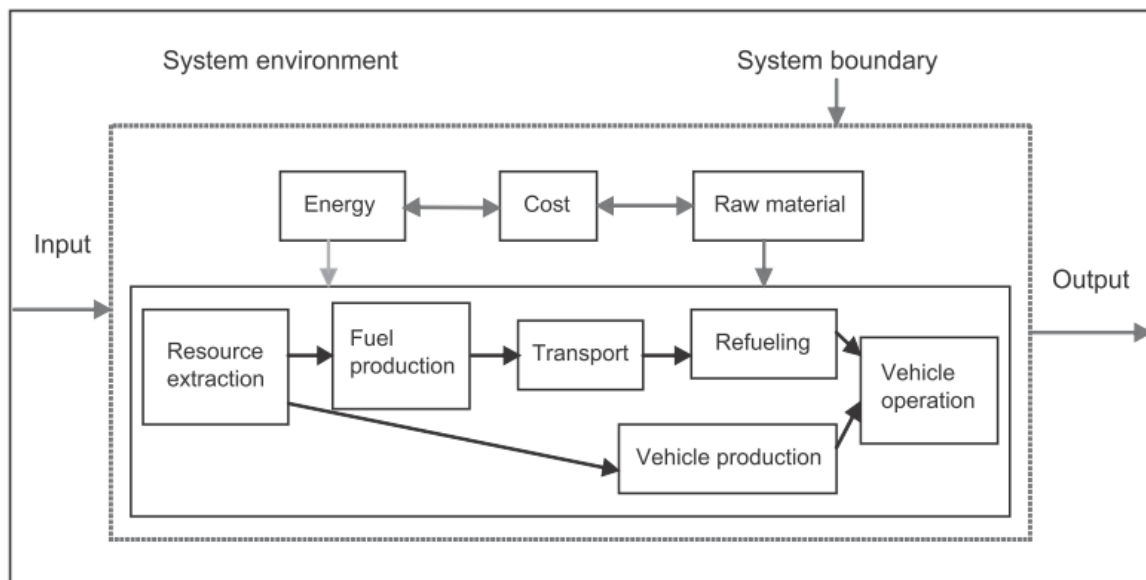
### 6.1 FUEL CELL VEHICLE DEVELOPMENT

Fuel cell vehicles (FCVs) technology provides potential of high efficiency and ultra-low emissions. Proton exchange membrane (PEM) fuel cell vehicles under development require hydrogen as a fuel. Among various ways of hydrogen generation, including on board and off boards, current questions remain which options is of most value from economical, environmental and efficient aspects. However, this focus of research should be based on context that extremely unbalanced energy status of China (The China sustainable energy program, 2010), i.e., concentrating on coal, lack of petroleum, and the potential for the further utilization of natural gas (NG).

This section is basically based on the results of a life-cycle assessment (LCA) of *C. Wang et al*, which is originally a technique for assessing environmental aspects along the continuum of a product's life, from raw material acquisition to its production and use and, eventually, its disuse (ISO, 1997-2000). However, with diffused use of LCA, its underlying principles, has been applied to other areas of rapid development, such as economic, technological, or social of products. *Wang et al.* (2005) have conducted a comprehensive study of the 3E (energy, environmental, economic) impacts of FCVs in a whole life cycle, i.e., from well to wheel, as shown in Fig. 15 (Wang et al., 2005).

Various fuel pathways (see table 10) have different 3E impacts. To present a comprehensive comparison of all possible fuel chains for FCVs in its full life cycle, they are selected based on:

- (1) The timeframe of this study is from now on to 5 or 10 years later.
- (2) From the view of sources utilization, the chosen primary energy sources must be widely available and be suitable for the Chinese energy structure.
- (3) The technical feasibility and commercial penetration of fuel production should be suitable not only for the current state of art but also for future technologies.
- (4) How to make full use of the existing infrastructure is also a very practical factor.



**FIGURE 15 SYSTEM BOUNDARY OF LIFE CYCLE (WANG ET AL., 2005).**

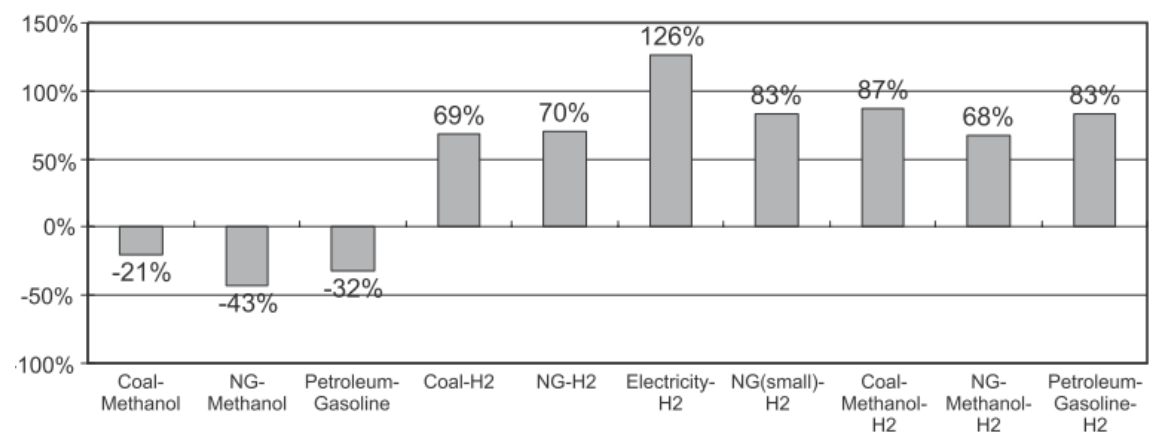
System boundary of this study started with the well, followed by the production and transportation of fuel, then the production, refueling, and vehicle operation, and finally, the purpose of disposal vehicles. The study also assumes that the vehicle's life span is 15 years, its life cycle mileage is 200,000 km. In addition, each fuel chain is a separate system with the same boundary.

**TABLE 10 FUEL CHAINS CHOSEN FOR COMPARISON IN WANG'S STUDY**

Path	Feedstock	Fuel	Refueling station	Vehicle type
Coal-MeOH	Coal	Coal-methanol	Methanol refueling	Methanol FCV
NG-MeOH	NG	NG-methanol	Methanol refueling	Methanol FCV
Oil-Gasoline	Oil	Oil-Gasoline	Gasoline refueling	Gasoline FCV
Coal-H2	Coal	Coal-H2 (central)	Hydrogen refueling	Hydrogen FCV
NG-H2	NG	NG-H2 (central)	Hydrogen refueling	Hydrogen FCV
Elec-H2	Coal	Coal-electricity	Electrolysis onsite-H2	Hydrogen FCV
NG-H2(onsite)	NG	NG	NG-H2	Hydrogen FCV
Coal-MeOH-H2	Coal	Coal-methanol	Methanol-GH2 onsite	Hydrogen FCV
NG-MeOH-H2	NG	NG-methanol	Methanol-GH2 onsite	Hydrogen FCV
Oil-Gasoline-H2	Oil	Oil-gasoline	Gasoline-GH2 onsite	Hydrogen FCV

### 6.1.1 COST ANALYSIS

Fuel costs contain fuel production, storage, transportation and refueling costs. In particular, for the H2 FCVs, it still includes the cost of hydrogen purification and compression.



**FIGURE 16 LIFE-CYCLE FUEL COST (RELATIVE TO ICEV) (WANG ET AL., 2005).**

There are mainly two sets of costs being considered in this study (Wang et al., 2005)—fuel and vehicle costs. The fuel cost includes all the costs relating with the fuel, while the vehicle cost includes not only

the purchase price of the vehicle, but also the cost of maintenance during the operation of the vehicle. The cost analysis in this study is based upon current and future prices and levels of technology.

Fig. 16 shows 10 fuel chains of different life-cycle fuel costs comparing to ICEV. From it, we can clearly see that the three life-cycle cost of fuel on board reforming FCVs have advantage over ICEV, and the H2 FCVs is just the opposite. As a traditional liquid fuels, methanol and gasoline storage and refueling are relatively easy implemented. Therefore, the costs of these fuel chains are lower than that of hydrogen fuel cell fuel chain, though its relatively low fuel economy. For the two fuel chains of large-scale production of hydrogen, they have similar fuel costs, which is slightly lower than other fuel chains of hydrogen fuel cell vehicle. The five chains of on board hydrogen fuel production, costs of electrics - H2 pathway fuel chain is the highest, while small-scale hydrogen production from methanol of small filling stations is better.

In addition, life cycle cost of a fuel chain is very important to consumers, this means that many owners will pay in their vehicles' life span, including fuel, purchasing, and vehicle operating costs.

### 6.1.2 ENERGY EFFICIENCY

Energy efficiency of the fuel chain depends on its state of the art and ability, so it can vary widely. When calculating the total energy efficiency of the life cycle, the energy efficiency of every technical process should be taken into account (Wang et al., 2005).

Fig. 17 represents 10 fuel chains given the relative energy efficiency of ICEV as baseline. In addition to the two fuel chains, the efficiency of all other FCVs are higher than ICEV, which can be clearly shown from a technical point of view of FCVs' advantage. In fact, the same with the two low-efficiency fuel chain of coal-based; other than its low efficiency, immature level of coal utilization technology in China is also an important factor. In contrast, both petrol and NG-based fuel chain is acceptable.

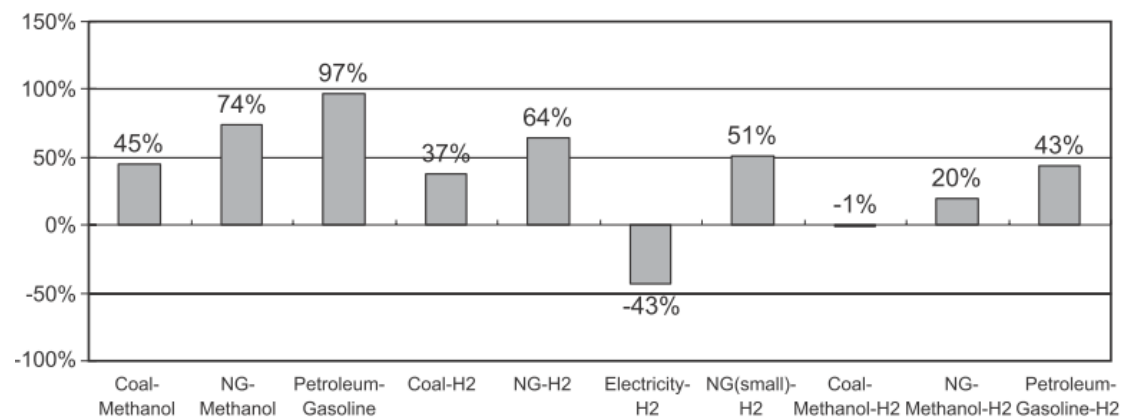


FIGURE 17 LIFE-CYCLE ENERGY EFFICIENCY (RELATIVE TO ICEV) (WANG ET AL., 2005)

We also found that onboard reforming fuel chains are slightly higher than that of H2 fuel cell vehicles fuel chain. This result is a balance of two factors: on the one hand, hydrogen FCVs run more efficiently

than on board reforming FCVs do; on the other hand, hydrogen purification, storage, transport and compression are of large energy consumption, which severely reduced efficiency of the H2 FCV fuel chain.

The electric - H2 fuel chain is of the worst energy efficiency. These are attributed to two low-efficiency power generation processes. Therefore, this fuel chain has certain limitations and should not be recommended.

### 6.1.3 ENVIRONMENTAL ASSESSMENT

The model estimates six major emissions, including carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOX), carbon monoxide (CO), total unburned hydrocarbon (THC), and particulate matter (PM). Among them, some are major greenhouse gases (GHG), while others are critical pollutants that are extremely destructive to the environment (Wang et al., 2005). From various environment preserving point of views, they play very important role in different aspects.

Life cycle emission is the sum of the fuel production process, storage, maintenance and fuel refueling of the life span of a vehicle. Table 11 shows the 10 relative life cycle emissions comparing to ICEV fuel chain.

Generally speaking, almost all NG-based fuel chains contribute equally or to a greater extent to the environment when compared with the ICEV, whereas coal-based pathways are not so optimistic due to the nature of coal energy, especially for the CO 2 emission, and oil-based fuel chains are the medium among the 10 pathways (Wang et al., 2005).

**TABLE 11 RELATIVE LIFE-CYCLE EMISSIONS OF 10 FUEL CHAINS BASED ON ICEV (WANG ET AL., 2005)**

	Coal- Methanol	NG- Methanol	Oil- Gasoline	Coal - H 2	NG - H 2	Electricity - H 2	NG - H 2 (small)	Coal- Methanol - H 2	NG- Methanol - H 2	Oil- Gasoline - H 2
CO 2	=	+	+	-	=	---	+	--	-	-
SO 2	+	++	+	-	-	---	=	--	=	--
NO X	++	++	++	++	+	---	++	++	++	++
CO	---	++	++	++	++	---	++	---	++	++
THC	++	++	+	++	++	-	++	++	+	+
PM	---	+	=	-	-	---	+	---	-	-



'+' Means 10–50% lower than the baseline; '-' means 10–50% higher than the baseline; '=' means b10% different from the baseline; '++' means N50% lower than the baseline; '—' means 50–100% higher than the baseline; '---' means N100% higher than the baseline.

On the other hand, similar analysis of the economic and energy efficiency, on-board reforming FCVs have slight advantage over the environmental contribution of H<sub>2</sub> FCVs, especially for NG-methanol fuel chain, followed by the results of the oil-gasoline fuel chain, and electricity-hydrogen fuel chain is still the of worst interest and unacceptable. For other paths, sequence and rules is not clear.

This phenomenon may be due to the following reason: A great deal of electric energy will be consumed during the processes of hydrogen production and compression, which, in turn, will bring about numerous emissions (Wang et al., 2005). Therefore, hydrogen FCVs cannot be said as absolutely 'zero-emission' vehicles, or in other words, emissions of H<sub>2</sub> FCVs, emitted mostly in the gas station than on the roads. Thus, through a comprehensive life-cycle emission comparison, on-board reform fuel chain will contribute less pollution than that of H<sub>2</sub> FCVs.

#### 6.1.4 CONCLUSION

For short term consideration, as shown in the results of cost, energy efficiency, and environment concerns, the NG-based fuel chains are of best interest of 3E impacts, and gasoline fuel chains are also acceptable, especially for its higher energy efficiency. In contrast, coal-based fuel chain is not optimistic. However, the comparison is not absolute, as diminishing oil resources and the great devotion to coal utilization in China.

Direct hydrogen FCVs introduction of mass production might be difficult business in the next decade, mainly due to the capital investment of hydrogen network and facilities are also too large to be acceptable. For the short term and regional applications, particularly demonstration of fuel cell vehicles fleet, hydrogen FCVs are still of feasibility.

As an option, gasoline FCVs have inevitable limitations, that is, a shortage of crude oil in China. Therefore, in contrast with H<sub>2</sub> and methanol FCVs, development of gasoline FCVs will increase the burden of oil imports, and even endanger national security. However, because of existing petrol filling station, and high efficiency of gasoline fuel chains, it is still of significance when considering about short term solution.

Relatively speaking, it is quite feasible to adopt methanol to facilitate the development of fuel cell vehicle with the benefits that making methanol from coal may effectively change the energy composition of China and enhance the utilization of coal energy. However, due to the poisonous nature of methanol, further research must be made to guarantee its safe application.

For long term consideration, since results of this research is based on the assumption that the electricity is generated totally from coal of low efficiency, conclusions may be different or even contradict with what is recommended for short term development.

First, coal will be the main energy source of China in the following decade, it is possible that the efficiency of coal burning will be improved and its negative impacts will be alleviated to certain extent in the near future. Since China has devoted great efforts in cleaner coal research, and is actively involved in international cooperation program with the US (IEA, 2009), it is likely that such activities and experiences to be gained will lead to improvement in coal use.

Secondly, conversion of coal to other energy has a promising future (IEA, 2009). Hydrogen, methanol and liquid coal are expected to be alternative for oil in long orientation. Coal-based co-production is the measure making best use of coal that it can produce chemical products, liquid fuels and electricity according to market demand and get maximum profit.

Thirdly, sustainable resources (e.g. hydro) are vast in China, wide application of such projects will result in a cleaner or even zero emission process of electricity generation.

## 6.2 BATTERY ELECTRIC VEHICLE DEVELOPMENT

As stated, for BEV the major barrier for introduction is technological problem, namely, the batteries. In order to gain more insights for this issue, a comparison of different types of batteries should be made. Life cycle assessment (LCA) allows practitioners to study the environment, impacts of the whole production from raw material procurement, use and disposal throughout life of the product. The so-called "cradle to grave" approach, so that LCA is unique and useful.

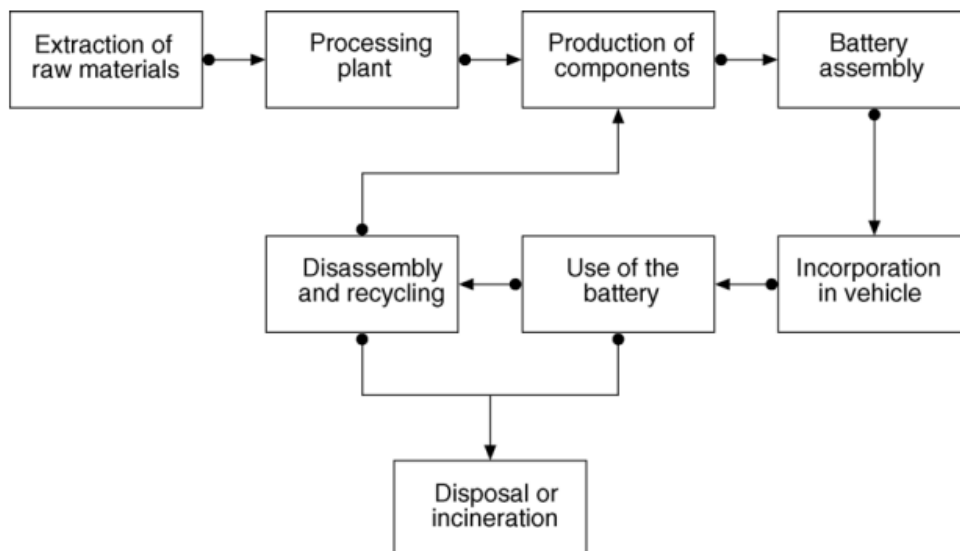


FIGURE 18 THE SCHEMATIZED LIFE CYCLE OF A BATTERY (VAN DEN BOSSCHE ET AL., 2006)

P. Van den Bossche et al. (2006) has built a model for such purpose. As several products have to be compared, an appropriate functional unit has been defined as following.

- the extraction of raw materials;

- the processing activities of the materials and components;
- the use phase of the battery;
- the recycling of discarded batteries;
- the final disposal or incineration.

A schematized overview of the life cycle of a battery is shown in Fig. 18.

## 6.2.1 GENERAL DESCRIPTION OF BATTERY

### 6.2.1.1 LEAD-ACID BATTERY

The lead-acid battery was invented by Gaston Planté in 1860. Today, as the oldest and best known electrochemical couple, it is the most widely used traction battery for industrial electric vehicles (Van den Bossche et al., 2006).

In its basic form, the lead-acid battery consists of a negative plate made from lead metal and a positive plate made from brown lead dioxide, submerged in an electrolyte consisting of diluted sulphuric acid. Lead-acid batteries are manufactured in different types and sizes according to their application (Matheys, Van Autenboer, 2007).

The need for maintenance and regular watering makes these batteries less suitable for use in consumer applications; for this reason, their use in electrically propelled road vehicles is limited to heavy-duty fleet vehicles such as buses (Matheys, Van Autenboer, 2007).

### 6.2.1.2 NICKEL-CADMIUM BATTERY

The nickel-cadmium battery also presents a positive electrode made from nickel oxide; the negative electrode however is made of metallic cadmium. The electrolyte consists of a lye solution of potassium hydroxide with an addition of lithium hydroxide, the latter having a stabilizing effect during cycling. The nominal cell voltage is 1.2 Volt.

Its historic development was parallel to nickel-iron and it offers the same characteristics as nickel-iron, such as a quite high specific energy compared to lead-acid, a good resistance to abuse and a long cycle life (Matheys, Van Autenboer, 2007). Its particular advantages however are a better operation at low temperatures, a slower self-discharge and a higher electrical efficiency leading to less maintenance and water consumption.

### 6.2.1.3 NICKEL METAL HYDRIDE BATTERY

The use of hydrogen as negative active material gives a good energy to weight ratio. Storing and maintaining hydrogen gas can be cumbersome however; to this effect, hydrogen can be stored in metal alloys, and thus one obtains the nickel-metal-hydride battery. The alloys used for this purpose are mostly proprietary, and are usually of the types AB 5 (e.g. LaNi 5) or AB 2 (e.g. TiNi 2).

Nickel-metal hydride batteries possess some characteristics making them suitable for use in electrically propelled vehicles. The fact that they are cadmium free is a selling argument in some markets where the use of cadmium is seen as an environmental concern (Matheys, Van Autenboer, 2007). From a technical viewpoint however, their specific energy is somewhat higher than nickel-cadmium, and; furthermore, they are well suited to fast charging.

A disadvantage however is their tendency to self-discharge, due to hydrogen diffusion through the electrolyte. Furthermore, high-current operation during charging (which is an exothermic reaction), makes thermal management and cooling of these batteries essential.

#### 6.2.1.4 LITHIUM-ION BATTERY

Lithium is the lightest metal element known and is under full consideration for high energy batteries. Several secondary battery technologies using lithium have been developed. Lithium-ion batteries work through the migration of lithium ions between a carbon anode and a lithium metal oxide alloy cathode. The electrolyte is an organic solution; no metallic lithium is used. Lithium-ion batteries have been proposed for both battery-electric vehicles, where they benefit of their excellent specific energy of up to 200 Wh/kg, and hybrid vehicles, making use of cells specifically designed for high power, where values up to 2000 W/kg can be reached (Matheys, Van Autenboer, 2007).

One main issue to be considered somewhat more acutely with lithium batteries compared to other battery technologies is safety. Lithium is very reactive, and abuse conditions such as crashes, fires and excessive temperature rises may cause uncontrolled energy releases which create hazardous situations (Matheys, Van Autenboer, 2007). The implementation of cell-level management and control systems is thus a dire necessity for any lithium-based system.

Although lithium batteries have taken a considerable share of the portable battery market, one has to recognize that high-power applications such as traction present different challenges (Tahil, 2010). Lithium batteries for traction are now available as prototypes and are on the brink of series production; further optimization as to life, system safety and stability and production cost is still being performed however, and the lithium systems can today not be considered yet as a fully commercially available product.

#### 6.2.1.5 HIGH-TEMPERATURE BATTERIES: THE SODIUM-NICKEL-CHLORIDE BATTERY

The sodium-nickel-chloride battery (known under its brand name Zebra) is characterised by its high operating temperature. It presents interesting opportunities for electrically propelled vehicles due to its high specific energy of typically 100 Wh/kg.

The electrodes of this battery consist, in charged state, of molten sodium and molten nickel chloride; the electrolyte is a solid aluminum oxide ceramic. In discharged state, the electrodes are sodium chloride and nickel.

These batteries have been successfully implemented in several electric vehicle designs, and present interesting opportunities for fleet applications (Legers, 2008). The sodium-nickel-chloride battery is fore mostly an “energy” battery and thus primarily suitable for battery-electric vehicles; its specific power being rather modest for hybrid applications.

### 6.2.2 ENVIRONMENTAL ASSESSMENT

Results of environment assessment based on the model above are shown in Table 12. When taking into account the battery's life cycle, it seems that the energy loss in the battery and energy loss due to the additional mass of battery is very significant to the environment. However, this effect is strongly dependent on electricity production. In the current calculation the European electricity production structure has been used, but its impact will be strongly decreased, if the use of renewable energy is implemented with greater depth. When considering environmental impact of batteries (not including the use phase), it appears that the effects of lead-acid batteries are the highest, followed by nickel-cadmium, lithium ion, nickel-nickel-hydrogen and sodium chloride.

In addition, it is noteworthy that the recycling phase to allow compensating the environmental impact for the production stage to a large extent.

**TABLE 12 ENVIRONMENTAL SCORES (ECO-INDICATOR POINTS) OF THE LIFE STAGES OF THE ASSESSED BATTERY TECHNOLOGIES (VAN DEN BOSSCHE ET AL., 2006)**

	<b>Production</b>	<b>Additional use (including mass and battery efficiency)</b>	<b>Recycling</b>	<b>Total</b>
<b>Lead-acid</b>	1091	221	-809	503
<b>Nickel-cadmium</b>	861	303	-620	544
<b>Nickel-metal hybride</b>	945	323	-777	491
<b>Lithium-ion</b>	361	89	-172	278
<b>Sodium-nickel chloride</b>	368	122	-256	234

An important conclusion is that the impact of assembly and production phase can be compensated largely when battery collection and recycling is performed in an effective way, on a large scale.

When excluding the energy losses during the use phase (due to the battery efficiencies and the additional masses of the batteries), the following environmental ranking is obtained (decreasing

environmental impact): lead–acid, nickel–cadmium, lithium-ion, nickel-metal hydride, sodium–nickel chloride (Van den Bossche et al., 2006).

### 6.2.3 COST ANTICIPATION

Ever since 1998, China’s government and private sectors have started a series of dynamic politics on development of battery industry. In relation with the national R&D program (863 program) many of the major Chinese battery companies have focused on traction battery development based on NiMH and lithium technologies (Matheys, Van Autenboer, 2007).

This emerging industry is in a very different situation compared to Europe, Japan and the United States for two main reasons:

- For the NiMH batteries and lithium-based materials which requires large amounts for raw materials are from China,
- Chinese manufacturing costs (as well as other industries) is much lower.

It is today impossible to anticipate the prices that will be used by Chinese Manufacturers in future, but it seems probable that the technical performances will be of the same order compared to the other country companies and the prices will be lower (Matheys, Van Autenboer, 2007).

The first estimation is based information provided by the recent study of SUBAT project:

- Ni-MH battery for energy applications (BEV): about 50% cost reduction seems to be possible, leading to price declines to a larger extent.
- Ni-MH battery for Electric Power Applications (hybrid) are not truly developed currently in China
- Lithium based energy applications: a cost 20 to 30% of the decline seems to be possible,
- Lithium based Power Application: a 30 to 40% reduction in costs, it seems impossible.

### 6.2.4 LITHIUM BATTERY DEVELOPMENT

The adoption of Lithium Ion battery technology for Electric Vehicles continues to gather momentum. The question of how much Lithium or Lithium Carbonate is required per kWh of battery storage capacity has become a matter of some importance due to the limited availability of Lithium for EV applications. The main factors which reduce the theoretical capacity of a LiIon battery are:

- Irreversible capacity loss: Lithium that becomes bound up in the anode and cathode and electrochemically inactive. This can be as high as 50% of the Lithium originally put into the cathode before the battery is charged for the first time (Tahil, 2010).
- Discharge rate: this is the major variable which reduces day to day effective capacity while the battery is in use. The Energy batteries required for PH(EV) use are more sensitive to this than power batteries and the problem is further exacerbated by using small batteries in a PHEV. Again, up to 50% of the effective capacity could be lost at medium to high speeds (Tahil, 2010). Manufacturer capacity figures that only apply at low discharge rates are of little use in

determining a realistic benchmark for PHEV battery capacity, for which capacity at the 1C rate at least should be used as a realistic indicator.

- Cycle life capacity fade: EV batteries will be 25% larger than the nominal or useable stated capacity to allow for capacity fade.

A real world EV Lilon battery will provide nominally some 25% of the theoretical energy capacity or 70 – 120 Wh/kg instead of 410 – 450 Wh/kg. This translates into a Lithium requirement of at least 320 g of Lithium (1.7 kg LCE) per kWh of available capacity. In addition, Lithium has to be added to this for the electrolyte, irreversible capacity loss and capacity fade. EV batteries will be 25% oversized to account for capacity fade. Then allowance has to be made for processing yields of an estimated 70% from the raw technical grade Lithium Carbonate plus inevitable losses in the use of high control purity Lithium Carbonate in the manufacture of the battery components themselves. LiMPO 4 batteries operate at lower voltage than LiMO 2 and therefore induce a further increase.

If one therefore allows 400 g of Lithium (2.1 kg LCE) per battery kWh with a 70% processing yield to produce that, an initial 3 kg of raw technical grade Lithium Carbonate will be required per kWh of final usable battery capacity (Tahil, 2010).

At 3 kg raw technical grade LCE per kWh, current global production of some 100,000 tonnes raw LCE would be sufficient, if available, for some 2 million 16 kWh batteries per year. Even at an optimistic 2 kg LCE per kWh assuming very high purity yields, production would be sufficient for only 3 million 16 kWh PHEV batteries per year (Tahil, 2010).

#### 6.2.4.1 RESOURCES

China is planning for the most significant increase in lithium carbonate production in the next 5 to 10 year program The Chinese government projected 55,000tpy of LCE by Citic Guoan at Qinghai (Tajinaier) alone by 2010. We choose to be more realistic in our assessment. Most of this growth may be destined for domestic consumption and the nascent electric car industry in China. This is more difficult to produce battery grade Li<sub>2</sub>CO<sub>3</sub> lithium carbonate from brine sources than it from the hard rock minerals, the production of lithium carbonate. Although brine sourced Li<sub>2</sub>CO<sub>3</sub> is much cheaper than that produced from minerals (spodumene) it has higher level of impurities (sodium, boron, calcium, magnesium) and is more technically demanding to purify. As the Chinese switch from Li<sub>2</sub>CO<sub>3</sub> produced from imported or domestic spodumene to Li<sub>2</sub>CO<sub>3</sub> produced from domestic brine, new and more complex processing will have to be established (Legers , 2008).

Obviously, if the lithium carbonate demand from portable electronics industry in the next 10 years continue its current high growth rates, intense competition, will arise between the automotive industry and electronics industry for supply of raw materials. Scheduled and possible increase in lithium carbonate production will not be able to meet the needs of these two industries. The portable electronics sector is experiencing chronic shortages of Lithium today and its growth prospects, driven

by new low cost products aimed at new multi-billion unit markets, do not appear to be undimmed (Legers , 2008).

Foreseeable Lithium production increases may be able to more or less match demand from the growing portable electronics society until 2015, at the risk of causing permanent environmental damage to the Andean Altiplano (Legers , 2008).

Realistic Lithium production increases have no visions for reaching the demands of an entire production and propulsion revolution in the Global Automotive Industry in the next decade.

Even if non-automotive Lithium demand was to level off at 120,000 tpy in the mid 2010s (50% higher than current demand), the level of surplus  $\text{Li}_2\text{CO}_3$  possibly available in the optimistic High Production Scenario in 2015 could only meet demand for 4 to 5 million GM Volt class vehicles and up to 8 million GM Volt class vehicles worldwide in 2020, or a small fraction of global automotive requirements (Baumgardner, 2010).

Finally, China's new brine-sourced  $\text{Li}_2\text{CO}_3$  may not be relied on by other parts of the world battery manufacturers for quality reasons, the domestic demand for electric vehicles and China's policies to reduce the export of strategic materials as currently being considered as rare earth metal.

The Salar de Uyuni is a very thinly dispersed resource and its realistic producible Lithium reserve is only in the order of 300,000 tonnes (Legers , 2008). These factors combined in two largest salt lithium deposit in combination means that it has to be very cautious and realistic in predicting possible future exercise of global lithium production.

#### 6.2.4.2 LITHIUM-AIR BATTERY DEVELOPMENT

The recent seminars, Computational Perspectives, attracted public and private sector scientists and engineers from all over the world. While sustainable energy alternatives continue to dominate conversations in environmental and industry circles, Argonne's battery research offers the promise of electric cars with 500-miles of power, though battery development for them may take another decade (Baumgardner, 2010).

Advanced Battery will bring a longer running time, to mobile phones and laptops. However, one of the biggest beneficiaries may be electric vehicles. Argonne has tested its lithium-ion battery in a Toyota Prius, running it on an on-site track the equivalent of the distance to California without ever having to stop. Currently, Argonne's engineers remain focused on lithium-ion batteries, which have already doubled the capacity of the more common acid based batteries. But through funding granted by the American Recovery and Reinvestment Act, the lab now has \$8.8 million to develop high-performance battery systems, such as lithium-air systems. These new systems could potentially increase battery life and power exponentially (Baumgardner, 2010).



What makes these battery systems work is the material within it. Common lead-acid batteries use water-based conductor, but the water will lead to rapidly decompose the acid limiting the power range and life span. Lithium-ion and futuristic lithium-air batteries will prolong battery life and increase voltage because component itself can last longer, and allows a higher conductivity. The benefits will be enormous, because it has the potential to hold more than 10 times the energy, which is a big breakthrough. In the early stages of the development of lithium-air batteries would compress air, increase a stable reaction in the surface of the energy stored by the battery electronics.

However, these advances are still in the development stage, which will not be seen at least in 10 years. But the advancement in technology is only a matter of time. Amine estimated by 2020, approximately 25 percent of the cars on the road will be electric. But major challenges remain, preventing these new battery systems from reaching consumers quickly. One is advancing the power potential of the battery but safety and cost also need to be addressed (Baumgardner, 2010).

### 6.2.5 CONCLUSION

This Market is a new one, from about 4 million of vehicles in 2003 and with a yearly increase of more than 12%, it becomes possible to reach a size of more than 8 million of vehicles/year in 2012 [75]. As a niche market, it is not so well known than others, making it difficult to predict reliably. However, some main features can be described and consequences can be analyzed basing on several different scenarios.

Even with the most efficient BEV, achieving a range of 300 mile would require 50kWh of batteries and the lifecycle cost would then be the same as the ICE and FCEV. However, for the most efficient BEV, if a range of only 50 mile is required, the lifecycle cost could be below \$5000, considerably less than any other option (Morrow, Karner, Francfort, 2008). Thus, for a city car, BEV has the potential to be the best option if the battery size can be constrained to the minimum.

The market will be mainly driven by fuel economy and government policies and the assumption of rapid growth of ultra-low emission vehicles, can be made for the following reasons: First, Chinese oil consumption increases very rapidly (about 30% per year) even though more than 50% is imported today (Matheys, Van Autenboer, 2007); Second, local pollution, has greatly increased in all major cities in China in the past few years; Third, China is one of the world's leading manufacturers of active substances of NiMH and lithium-based batter; Finally, the advanced automotive market may be a way to raise China's auto industry development

In order to crash the barriers of BEV, the following recommendations could be formulated for China:

- Development of low prices little hybrids of all types, advanced electric vehicles
- Development of the electric two wheelers market (very important in China)
- Development of the hybrid and electric bus market
- Actively involved in activities exploring lithium batteries' potential

In all cases, the Chinese battery market will increase based on an internal production and consumption. This increase could have a consequence on the other markets (European and US) with an important decrease of the battery prices (NiMH, Lithium based).

## 6.3 HYBRID ELECTRIC VEHICLE

Pure BEVs and FCEVs present differences in attributes such as range, efficiency, cost, and recharging methods. In addition it is essential to consider the relevance of the technologies to the application. As both the BEV and the FCEV rely upon an electric power train, and thus the remainder of the vehicle can effectively be identical, it is evident that the two technologies should be considered together rather than separately, in a hybrid solution (State Statistical Bureau of China, 2007).

### 6.3.1 PLUG-IN HYBRID (PHEV)

The urban air pollution and greenhouse gases and oil consumption of PHEVs will depend on their all electric range (AER) and vehicle control logic between the battery/electric and internal combustion engines propulsion, will determine the percentage of energy drawn from electrical grid. The AER depends on the energy storage capacity of the PHEV's battery bank. The larger the battery capacity, the longer the vehicle can travel alone depend on power grid, the less frequently it will need to run the vehicle on-board power supply. The AER of a PHEV is the distance that the vehicle can travel exclusively on battery power, the so-called "charge depleting" (CD) mode. Once the battery reaches a lower limit of state of charge (SOC) in this mode, then the engine or fuel cell is turned on and the vehicle operates in the charge sustaining mode, similar to a hybrid electric vehicle where the load is shared by the battery bank and the engine or fuel cell (Thomas, 2009).

**TABLE 13 ENVIRONMENTAL SCORES (ECO-INDICATOR POINTS) OF THE LIFE STAGES OF THE ASSESSED BATTERY TECHNOLOGIES (VAN DEN BOSSCHE ET AL., 2006)**

	Production	Recycling	Total
<b>Pb-acid</b>	95.0	-70.5	24.5
<b>Ni-Cd</b>	64.4	-46.4	18.0
<b>NiMH</b>	26.8	-22.1	4.8
<b>Li-ion</b>	13.7	-6.6	7.1
<b>NaNiCl</b>	133.0	-92.6	40.4

However, some authors point out that the existing prototype PHEVs do not be responsible for binary 'all electric' HEV-like charge sustaining mode after charge depleting mode followed. For a given size of battery bank, the range of a PHEV can be extended significantly before batteries need recharging by turning on the engine or fuel cell whenever the vehicle power demand exceeds some threshold. In

consumption patterns in the hybrid charge, the vehicle battery power is conserved during low power demand. The performance of the PHEV is thereby enhanced for a given size of battery in terms of the distance that can be traveled before the battery needs to be plugged in (Thomas, 2009). Lower power batteries can be used for a given all-electric range, which significantly reduces the cost, weight, and volume of the battery bank.

The main technical attributes of the various battery technologies are shown in Table 13. The role of the battery in an HEV is different from its role in a BEV.

### 6.3.2 FUEL CELL HYBRID ELECTRIC VEHICLE (FCHEV)

The FCHEV was assumed to be a plug-in hybrid with the capability to recharge the batteries when possible and a hydrogen fuel cell range extender. G.J. Offer et al.(2009) compares battery electric vehicles (BEV) to hydrogen fuel cell electric vehicles (FCEV) and hydrogen fuel cell plug-in hybrid vehicles (FCHEV). Qualitative comparison of the technical and infrastructure needs, and more than 100,000 miles of powertrain quantitative life-cycle cost comparison, accounting the capital and fuel cost. Common Vehicle platforms are assumed. 2030 scenario was discussed and compared to the traditional gasoline internal combustion engine (ICE) powertrain. A comprehensive sensitivity analysis shows that in 2030 FCEVs can reach equivalence with life cycle cost of conventional gasoline cars. However, both BEV and FCHEV greatly reduced life cycle cost.

### 6.3.3 CONCLUSIONS

First, from aspect of capital costs, in 2010 FCVs, BEVs and FCHEVs are far more than that of traditional internal combustion engine power system. However, in 2030 capital costs will significantly decrease, whereas FCHEV shows the lowest capital cost, followed by BEVs and FCVs. The ICE powertrain cost is still cheaper in 2030, but when the lifetime fuel cost will factor significantly in the changing situation.

Secondly, in terms of fuel costs, the cost cannot be accurately predicted the future. However, some reasonable assumptions can be made. The TtW efficiency for each powertrain significantly affects electric cars more than gasoline or hydrogen cars, in achieving far higher miles per GJ. In 2030, BEVs and FCHEVs relatively insensitive to the changes fuel (power) cost, while FCEVs and ICEs display remarkable sensitivity to hydrogen and gasoline prices respectively. This is partly due to different power system efficiency.

Third, with respect to 100,000 miles total life cycle cost, FCHEVs seems a little cheaper than that of BEV, but with a overall greater sensitivity to the joint (capital and operating) costs. Both ICEs products and FCEVs are greater than FCHEVs and BEVs in life cycle cost, about 1.75 times higher.

However, many simulation models suggest that (Thomas, 2009) the hydrogen-powered fuel cell electric vehicle and the battery-electric vehicle are the only options that would eliminate nearly all controllable urban air pollution from the transportation sector by 2100; all other vehicle/fuel options including both gasoline and biofuel PHEVs would produce essentially the same or greater urban air

pollution as the existing car fleet due to increased vehicle miles traveled over the century. From this point of view, only zero-emission vehicles can be considered as viable alternatives for long term orientation.

## 7 SOCIO-TECHNICAL SCENARIOS OF ELECTRIC VEHICLES' DEVELOPMENT IN CHINA

In this chapter, socio-technical scenarios for China's transition towards transportation with electric vehicle are made. Firstly, the driving forces and tipping points are identified based on the previous analysis, then the scenarios are fully illustrated. In the end, a comparison of different scenarios is shown in a diagram.

Firstly, brief version of the scenario will be made. For that purpose, the links between the crucial elements of landscape, regime and niche will be combined to form initial paths. This will include the niches that will break through, together with the related time-path and the reasons behind such developments. Relevant cross-linking of niches and expected market share would also be incorporated. In this analysis, I distinguish the paths for the regime level under the four transition phases namely, pre-development, take-off, breakthrough, and stabilization. After that, a consistency check is made to control if the assumptions are coherent with each other. Finally, the scenario skeleton will be further elaborated in a much more detailed level. Special attention is paid to make sure the linkages made are coherent with the multi-level perspective.

**TABLE 14 OVERALL STRUCTURE OF 4 SCENARIOS**

Scenario	Driving force/factors	Policy direction
<b>Scenario 1(1A&amp;1B)</b>	Energy security	<ul style="list-style-type: none"> <li>• Coal technology (efficiency)</li> <li>• Energy policy (fuel tax)</li> <li>• FCV fuel chains</li> </ul>
<b>Scenario 2 (2A&amp;2B)</b>	Environmental concern	<ul style="list-style-type: none"> <li>• Electricity generation</li> <li>• Sustainable energy diffusion</li> <li>• Consumer type</li> <li>• FCV fuel chains</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Scenario A (1A&amp;2A) (uncoordinated response)</b></li> <li>• <b>Scenario B (1B&amp;2B) (coordinated response)</b></li> </ul>	Coordinated response-uncoordinated response	<ul style="list-style-type: none"> <li>• Fuel efficiency regulations</li> <li>• International R&amp;D cooperation</li> <li>• Conglomeration of domestic market</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Beijing (horizontal pattern)</b></li> <li>• <b>Shanghai (vertical pattern)</b></li> </ul>	Horizontal-vertical pattern (external adaptation-internal adaptation)	<ul style="list-style-type: none"> <li>• International R&amp;D cooperation</li> <li>• Infrastructure construction</li> <li>• Battery price</li> </ul>

The overall structure of the four scenarios is shown in table 14. They are driving forces and factors which set different trajectory for each scenario.

Concern for energy security and environmental problems are considered major driving forces for transition of electric vehicles to take place. Environmental problems have been hot topic in recent years, some results of analysis (Thomas, 2009) and simulations have shown that without control of relevant issues, environment conditions in China will no doubt be deteriorated. Furthermore, international society has impose pressure on China for its growing green house gas emission, which aggravated the already endangered global warming effects. On the other hand, China's oil consumption keep rising in the last decade, its dependency on oil import is becoming stronger, which contrast with the reality that infertile reservation of oil in China. As a country of strong sense of centralization, this situation will no doubt cause problems in the future. Another aspect which is often considered a driving force in some other scenarios (Meyer, Winebrake, 2009) is fuel price. However, dynamic fuel price is not considered driving force of socio-technical scenario, due to its rather stable performance in recent years. Driving forces adopted in this report are shown in table 18.

For local governments' administration pattern, their relationship with industries play an important role, which are categorized as horizontal pattern or vertical pattern. Obviously, there are no pure forms for horizontal structure or vertical structure, and most local governments encompass both patterns. However, to address it explicitly, pure forms have to be adopted in construction of scenarios. Beijing and Shanghai are taken as representative of horizontal structure and vertical structure respectively. And in each scenario, they have different reaction towards dynamic situation and interact diversely, which result in different outcomes for each city. Here, I assume cities with horizontal pattern have a preference for external adaptation, whereas cities with vertical pattern prefer internal adaptation instead. Because vertical cities tend to have more powerful enterprises, they have long orientation for the future and are mostly capable of managing incremental improvement, and more importantly they impose sufficient resistance to niche competitors. While on the other hand, horizontal style cities are better at nurturing niche industries, and help them grow in the process. From application perspective, the two cities do not necessarily represent themselves in the real world but local governments with similar administration pattern, in that sense, the cities could be Guangzhou, Wuhan, or Harbin etc..

As an important dimension of the quasi evolutionary model, level of coordination seeks to distinguish between regime transformations that are intended and purposively governed, and those that are the unintended and contingent outcomes of historical processes. The uncoordinated situation would only be adopted at the beginning of the scenario B, and coordinated response will take over once the market has drawn enough attention. The importance of fuel efficiency regulations has been illustrated more specifically in Chapter 5, and in this case it is involved as initial policy of scenario B with coordinated response at the beginning. Intensification of these regulations is important factors that cause different consequences between scenarios A and B (e.g. scenario 1A and 1B).

**TABLE 15 INFLUENCING FACTORS AND EFFECTS OF PUBLIC ACCEPTANCE**

Contributing factors	Influencing factors	Effects
<ul style="list-style-type: none"> <li>Infrastructure</li> <li>Model improvement</li> </ul> <p>(reinforce effects)</p>	<p>Preferring mature product</p> <p>Easier influenced by people around</p>	<ul style="list-style-type: none"> <li>Consumer type</li> <li>Model improvement</li> <li>Battery manufacture transition</li> </ul>
<ul style="list-style-type: none"> <li>Battery price</li> <li>Production scale (reinforce effects)</li> </ul>	<p>Economical concern</p>	
<ul style="list-style-type: none"> <li>Lithium technology</li> <li>Infrastructure</li> </ul>	<p>Flexible mobility need</p>	
<ul style="list-style-type: none"> <li>International cooperation</li> <li>Fuel price</li> </ul>	<p>R&amp;D Increasing concern for fuel efficiency</p>	

Public acceptance is a key tipping point in electric vehicles’ large scale introduction. As mentioned in Chapter 5, the most significant aspects considered by the general public are shown in table 15. Some practical contributing factors are identified for each of these five aspects. One unique characteristic among the five is the second one, *easier influenced by people around*, which is not a typical factor that would influence public acceptance directly. But a reinforce effect is guaranteed once the circle is started, the effects, whether it is positive or negative, will get stronger during this process. And *effects* are the changes caused by increase or decrease of public acceptance.

**TABLE 16 UNCERTAINTY OF THIS SCENARIOS**

Uncertainty	Likelihood	Effects
<p>Battery performance break through (Lithium technology)</p>	<p>Long term possibility</p>	<ul style="list-style-type: none"> <li>Battery price</li> <li>BEV performance</li> </ul>
<p>Natural gas exploring</p>	<p>Possibility</p>	<p>FCV fuel chains</p>

Some uncertainties exist in pathway of China’s transition. Among all the uncertainties identified in Chapter 4 and Chapter 6, breakthrough of battery technology and China’s exploration of natural gas reservation remain most important of all. An overall breakthrough of battery technology is possible to be achieved by successful transition of electric two wheels (E2W) battery manufactures, however, that would not be an easy task. A successful transition management has to be carried out to create a

'purposive transition' (Heffner et al., 2007). On the other hand, natural gas exploring has huge potential to overthrow China's energy proportion. Thus, these two events will significantly result in differences in the socio-technical scenarios, due to their highly graded probability and the following impacts. They are shown in table 16.

## 7.1 2000-2010 THE PRE-FUTURE

At the beginning of the 21st century, increased concern over the environmental impact of the petroleum-based transportation infrastructure, along with the specter of peak oil, led to renewed interest in an electric transportation infrastructure. As such, vehicles which can potentially be powered by renewable energy sources, such as hybrid electric vehicles, plug-in hybrids and battery electric vehicles, are becoming more popular (IEA, 2007).

In January 1990, General Motors' President introduced its EV concept two-seater, the "Impact," at the Los Angeles Auto Show. That September, the California Air Resources Board mandated major-automaker sales of EVs, in phases starting in 1998. From 1996 to 1998 GM produced 1117 EV1s, 800 of which were made available through three-year leases.

Chrysler, Ford, GM, Honda, Nissan and Toyota also produced limited numbers of EVs for California drivers. In 2003, upon the expiration of GM's EV1 leases, GM crushed them. The crushing has variously been attributed to 1) the auto industry's successful federal court challenge to California's zero-emissions vehicle mandate, 2) a federal regulation requiring GM to produce and maintain spare parts for the few thousands EV1s and 3) the success of the oil and auto industries' media campaign to reduce public acceptance of electric vehicles.

Honda, Nissan and Toyota also repossessed and crushed most of their EVs, which, like the GM EV1s, had been available only by closed-end lease. After public protests, Toyota sold 200 of its RAV EVs to eager buyers; they now sell, five years later, at over their original forty-thousand-dollar price. The production of the Citroën Berlingo Electrique stopped in September 2005.

With increasing prices of gasoline, electric vehicles are hitting the mainstream (Debra, Carlton Harrell, 2008) Major car makers, such as Daimler AG, Toyota Motor Corp., General Motors Corp., Renault SA, Peugeot-Citroen, VW, Nissan and Mitsubishi Corp., are developing new-generation electric vehicles (Taylor, 2008).

Many electric vehicle companies are looking to China as the leader of future electric car implementation around the world (IEA, 2007). In April 2009, Chinese officials announced their plan to make China the world's largest producer of electric cars. The Renault-Nissan Alliance will work with China's Ministry of Industry and Information Technology (MITI) to help set up battery recharging networks throughout the city of Wuhan, the pilot city in the country's electrical vehicle pilot program. The corporation plans to have electric vehicles on the market by 2011. According to an April 10, 2009



*New York Times* Article entitled “China Outlines Plans for Making Cars,” auto manufacturers will possess the opportunity to successfully market their cars to Chinese consumers due to the short and slow commutes that characterize Chinese transportation, and Chinese consumers generally diminished experience with high powered gasoline-powered cars, subsequently diminishing the hindering nature of lower powered electric vehicles. Furthermore, in an attempt to design a program with incentives for buyers, MITI intends to give large subsidies to buyers of electric cars; the country has 10 billion Yuan, almost 1.5 billion U.S. dollars, to boost the automotive industry’s efforts towards modernization (Bradsher, 2009).

## 7.2 SCENARIO 1A

Driving force (or seed in van Bree, et al., 2010) of Scenario 1A is concern for energy security. As more and more oil consumption has led China to be a highly oil dependent country, which is insecure considering the dynamic and unstable situation of oil supply countries. In this scenario, no particular fuel efficiency regulation has been implemented. This regulation and its possible effects are illustrated more specifically in Chapter 4.4.

### 7.2.1 TAKING OFF

As alternative energy for oil, coal technology overall has to be the focus for its abundant reservation in China. However, there is still much to improve for its efficiency and negative environmental effects. General energy proportion has more dependence on coal energy, so that electricity generation plants emit more pollution than before. Environment of the city become much better at the cost of deterioration of the regions around energy plants.

To reduce oil consumption gradually, the most direct fiscal tool is to increase fuel tax. Public transportation win favorability of the public due to rising maintenance costs of vehicles, sales of private vehicles do not meet the expectation of manufactures. Rising fuel tax increase concern for energy efficiency of vehicles from the general public. Manufactures feel the pressure to improve existing models to more low-ultra-emit ones. Foreign carmakers have more incentives to transfer their energy efficient technology to their Chinese cooperators. For those who fail to keep up with this new trend may have to withdraw from China’s market, or at least cut their sales here. For domestic carmakers, some small ones might be purchased by more capable firms, who have the ability to survive and thrive in this dynamic market. However, gap still existed in domestic manufactures and leading international firms from technology perspective. Only the strongest ones would survive through either technology breakthrough by oneself or cooperation with international firms to have technology transferred.

In this case, standards (fuel efficiency regulations) are following markets trends instead of leading it.

Hybrid vehicles win favorability for its applicable technology, lower requirements for complementary goods and high energy efficiency. More manufactures jump into this field to sustain their market share.

As fossil based energy is discouraged, on the other hand, other energy based methods are greatly motivated. Coal energy will be restored in methanol or hydrogen, which has relatively high efficiency as well as low cost, and comparatively create lower harm to environment. For fuel cell vehicle, the more favored fuel chain are coal-methanol, coal-hydrogen. As an uncertainty that natural gas's exploration, if large amount of reservation are to be found, NG-methanol fuel chain will hit the mainstream its overall superior 3E(environmental, economical, energy ) effects.

Beijing, as a representative of local government, who implement horizontal pattern in industry administration, is more used to develop flourished niche market for innovation activities. However, an uncoordinated response is expected at the beginning. As long as the pressure of domestic carmakers is felt by the local authority, which will more likely to take actions and provide incumbents for them to develop. Under such circumstances, technology break through is more likely to take place. For domestic carmakers, they have more odds to develop into a technology independent industry. However, analytical speaking, the lack of clear articulation and coordination obscure the particular end-points for the transformation, compounding uncertainty over appropriate governance measures [10].

Shanghai's local government as a typical vertical administered authority, has a closer relationship with conglomerated industries. The city has history of cooperation with auto industry, which is willing to invest initial capital to facilitate relevant program. Thus, infrastructure construction, mass production and intensive R&D cooperation are likely to take place here faster than any other place in China. Initial investment can provide more sufficient infrastructure, economy scale will bring lower battery price and a mature lines of products at a faster speed than other cities in China. However, with insufficient governance involvement at the beginning, trajectories of change may be radically altered by internal processes without being associated with discontinuities in the actors, networks and institutions involved in the regime [10]. After all, these result in a widening up of public acceptance. More HEV models are introduced and tend to be adopted at an early stage. Environment of the city is much improved. Sales expectation here is more optimistic than other cities in China. Traffic congestion remains problems, since number of vehicles is still steadily rising.

### 7.2.2 BREAK THROUGH

On the other hand, as coal technology is widely used, and its negative effects become so obvious that it is drawing more attention from industry and research institutions than ever before. Although it has the potential to be improved to a large extent, in the end coal energy's limitations have to be confronted. Urgency for finding a more harmless alternative energy source is delivered to the government and society. Efforts for exploration of natural gas reservation are doubled. A series of

sustainable energy is applicable especially in the rural area, which will be listed with higher priority since the environmental pressure is unprecedentedly high in these areas. Another option here could be nuclear power plants, as advent of its technology, its negative effects will decrease to some extent, however, nuclear wastes caused by wide diffusion of nuclear energy application remain problems around the world.

Hybrid vehicles win favorability for its applicable technology, lower requirements for complementary goods and high energy efficiency. More manufactures jump into this field to sustain their market share. As more models come up, this market become mature, the public has accepted it as a applicable product, and it is widely diffused in everyday life.

Since city like Shanghai, is already taking off as leader of HEV and energy efficient vehicles. The niche market the Beijing government would like to encourage will be more cutting-edge toward zero emission vehicles (ZEV). In the meantime, dependence on public transport remains high, which motivated the local government to improve its infrastructure ever since. Thus it results in a rather high completion level of public transport system.

As private use of vehicles is not greatly discouraged in Shanghai city, the total amount of energy use is not likely to decline. After some time, the city feel the need to also focus on zero emission vehicles, for concerns of ever growing oil consumption as wells as environmental issue. More importantly, stronger auto market here has to be fed. A transition from HEV to ZEV has to take place.

In Beijing's niche market, after overall performance of electric vehicles is improved to satisfy mobility need of users, only a relatively small proportion of EV are introduced to the public at the beginning. It is a slow process, since the public transport network is perfecting itself all along, which reduce environment and energy problems to a large extent. Attributes of battery can be improved very much, greater scale for production is required to obtain a lower price, which may serve the need for city like Shanghai, since it is searching for its partner as technology provider.

### 7.2.3 STABILIZATION

China's overall carbon emission level has not decreased significantly, although the cities' environment condition has been much improved due to transition towards clean vehicles. Even though sustainable energy plants are increasing because of increasing demand for energy, its speed fails to keep up with it. And the country overall still suffered from environmental problems.

After expanded needs for ZEV, FCV's market place has to be evaluated together with BEV. Considering limitation of Lithium source, its market infiltration power can also be limited, except for major breakthrough in material utilization. A more intensive competition may take place between different fuel chains of FCV. Batter recycling industry grow bigger, efficiency of material utilization has been much greatly improved.

Hydrogen technology emerges as the priority of sustainable development in cities. However, without clean energy source, its further expanding is to create another trouble. Natural gas exploration becomes important in this scenario, or equivalently cleaner coal utilization and sustainable energy source diffusion. In optimistic scenario, if any one of these three could be achieved, clean fuel chains can be applied in overall China, both urban and rural areas included. For a worse scenario, a trade-off has to be made between zero emission cities and less contaminated country side. As coal-methanol fuel chain to be adopted as a balanced solution, while coal-hydrogen can be adopted as a more protective measure for the cities' environment.

Since China is stepping into an 'elder society' from 2020, Beijing's urbanization level and mobility needs are stable or even reduced. Well functioned public transport network can satisfy most of the mobility needs, so does its influence on citizens' behavior. As city don't experience much environment and energy pressure, they have relatively low priority for investment of EV's infrastructure, BEV may serve the need well with lower requirements for complementary goods and its matured attributes of performance.

Since stronger mobility needs is expected to take place in Shanghai, FCV tend to win favorability of the city. Highly diffused HEV provide a foundation for infrastructure improvement. Hydrogen vehicles are able to solve both problems the city is confronting, and other fuel cell vehicles may also well developed in the process.

## 7.3 SCENARIO 1B

Driving force (or seed) of Scenario 1A is concern for energy security. As more and more oil consumption has led China to be a highly oil dependent country, which is insecure considering the dynamic and unstable situation of oil supply countries. In this scenario, fuel efficiency regulation has been implemented. This regulation and its possible effects are illustrated more specifically in Chapter 4.4.

### 7.3.1 OPENING UP

As alternative energy for oil, coal technology overall has to be the focus for its abundant reservation in China. However, there is still much to improve for its efficiency and negative environmental effects. General energy proportion has more dependence on coal energy, so that electricity generation plants emit more pollution than before. Public transportation win favorability of the public, sales of private vehicles do not meet the expectation of manufactures. Environment of the city become much better at the cost of deterioration of the regions around energy plants.

To reduce oil consumption gradually, the most direct fiscal tool is to increase fuel tax. Rising fuel tax increase concern for energy efficiency of vehicles from the general public. Manufactures feel the pressure to improve existing models to more low-ultra-emit ones. Foreign carmakers will more likely to transfer their energy efficient technology to their Chinese cooperators. For those who fail to keep

up with this new trend may have to withdraw from China's market, or at least cut their sales here. For domestic carmakers, some small ones might be purchased by more capable firms, who have the ability to survive and thrive in this dynamic market. However, gap still existed in domestic manufactures and leading international firms from technology perspective. Only the strongest ones would survive through either technology breakthrough by oneself or cooperation with international firms to have technology transferred.

In this case, markets trends are following standards (fuel efficiency regulations).

Hybrid vehicles win favorability for its applicable technology, lower requirements for complementary goods and high energy efficiency. More manufactures jump into this field to sustain their market share.

As oil based energy is discouraged, on the other hand, other energy based methods are greatly motivated. Coal energy will be restored in methanol or hydrogen, which has relatively high efficiency as well as low cost, and comparatively create lower harm to environment. As an uncertainty that natural gas's exploration, if large amount of reservation are to be found, NG-methanol fuel chain will hit the mainstream its overall superior 3E(environmental, economical, energy ) effects.

Fuel efficiency regulations are issued to set higher emission standards. At the meantime, more rigid regulations come to place. It serves to speed up this process, and more domestic carmakers fail to meet the standards in the due process. in this case, they don't have the time that low vehicle price may buy them to develop for themselves as in the previous scenario. Thus less domestic firms would survive. On the other hand, it pushes domestic to engage in more intensive cooperation with international technology leading firms to accelerate this technology transfer.

Beijing, as a representative of local government, who implement horizontal pattern in industry administration, is more used to develop flourished niche market for innovation activities. In this case, Beijing being an active guiding role for transition management, which is a deliberate attempt to change the regime according to a consensus guiding vision. Key to the transition management projects is the greater role afforded to external social actors, both in articulating pressure for change, and in providing the resources, capabilities and networks that condition the responses [10]. As long as the pressure of domestic carmakers is felt by the local authority, which will more likely to take actions and provide incumbents for them to develop. Under such circumstances, technology break through is more likely to take place. For domestic carmakers, they have more odds to develop into a technology independent industry. However, in this case, there are fewer companies available to engage in research activities.

Shanghai's local government as a typical vertical administered authority, has a closer relationship with conglomerated industries. The city has history of cooperation with auto industry, which is willing to invest initial capital to facilitate relevant program. Thus, infrastructure construction, mass production

and intensive R&D cooperation are likely to take place here faster than any other place in China. Initial investment can provide more sufficient infrastructure, economy scale will bring lower battery price and a mature lines of products at a faster speed than other cities in China. Analytical speaking, Decisions over future technological choices will be guided by past experience. Thus, the transformation process will tend to be incremental and path following [10]. All these result in a widening up of public acceptance. More HEV models tend to be adopted at an early stage. Environment of the city is much improved. Sales expectation here is more optimistic than any other place in China. Traffic congestion remain problems, since number of vehicles are still steadily rising.

Since city like Shanghai, is already taking off as leader of HEV and energy efficient vehicles. The niche market the Beijing government would like to encourage will be a more cutting market toward zero emission vehicles. And new firms from niche market come to play, instead of conventional auto market seeks to transform. In the meantime, dependence on public transport remains high, which motivated the local government to improve its infrastructure ever since. Thus it results in a rather high completion level of public transport system.

### 7.3.2 BREAK THROUGH

On the other hand, as coal technology is widely used, and its negative effects become so obvious that it is drawing attention from industry and research institutions than ever before. It can be improved to some extent, however, finally coal energy's limitations have to be confronted. Finding a more harmless alternative energy source is urgent. (Natural gas may be it for an optimistic scenario.) A series of sustainable energy is applicable especially in the rural area, which will win more priority as the environmental pressure is unprecedentedly high in these areas. Another option here could be nuclear power plants, as advent of its technology, its negative effects will reduce, however, nuclear wastes remain problems around the world.

Hybrid vehicles win favorability for its applicable technology, lower requirements for complementary goods and high energy efficiency. More manufactures jump into this field to sustain their market share. As more models come up, this market become more and more mature, which rise public acceptance to a large extent.

Niche market in Beijing emerges as a new one. Because of government's regulations in favor of incumbent EV industries, it's developing at a fast speed. At the same time, research institutes actively involved in research and design of new emerging firms, which accelerate this developing process. As a result, instead of extension of conventional vehicles, innovative models come up as the new generation ZEV.

In Beijing's niche market, after overall performance of electric vehicles is improved to satisfy mobility need of users, only a relatively small proportion of EV are introduced to the public at the beginning. It is a slow process, since the public transport network is perfecting itself all along, which reduce environment and energy problems to a large extent. Attributes of battery can be improved very much,

greater scale for production is required to obtain a lower price, meanwhile, it is an opportunity for China's to start its self-independent auto makers, the nation may be initial capital provider for these firms. If so, competition between conventional auto industry and newly emerged EV industry may take place.

As more models come up as extension of conventional vehicles, automakers in Shanghai experience a evolutionary transition, which are favored by the public for their products' reliability, completeness of complementary goods.

As the private use of vehicles is not greatly discouraged in this city, the total amount of energy use is not likely to decline. After some time, the city feel the need to also focus on zero emission vehicles, for concerns of ever growing oil consumption as wells as environmental issue. More importantly, stronger auto market here has to be fed. A transition from HEV to ZEV has to take place.

### 7.3.3 STABILIZATION

After expanded needs for ZEV, FCV's market place has to be evaluated together with BEV. Considering limitation of Lithium source, its market infiltration power can also be limited, except for major breakthrough in material utilization. A more intensive competition may take place between different fuel chains of FCV. Batter recycling industry grow more than ever, efficiency of material utilization has been much greatly improved.

Hydrogen technology emerges as the priority of sustainable development in cities. However, without clean energy source, its rising is to create another trouble. Natural gas exploration becomes important in this scenario, or equivalently cleaner coal utilization and sustainable energy source diffusion. In optimistic scenario, if any one of these three could be achieved, clean fuel chains can be applied in overall China, both urban and rural areas included. For a worse scenario, a trade-off has to be made between zero emission cities and less contaminated country side. As coal-methanol fuel chain to be adopted as a balanced solution, while coal-hydrogen can be adopted as a more protective measure for the cities' environment.

As more matured technology applied to new auto industry, stricter regulations are expected to control vehicle stock in cities. If this progress is faster than that of sustainable energy source transition, it is likely that pollution along the fuel chain will incline to move away from the cities and onwards to regions around energy plants.

With completely new models, new standards come along, both for emission and design parameter. This provides China the opportunity to be a major role in auto industry.

Since stronger mobility needs is expected to take place in Shanghai, FCV tend to win favorability of the city. Hydrogen vehicles are able to solve both problems the city is confronting, and other fuel cell vehicles may also well developed in the process.

It is more difficult in this case for conventional industry to keep up with the new EV industry with the pressing energy efficiency regulations. Many conventional automakers failing to abandon their former production lines, which has involved too much sunk cost, lost the battle and withdraw from the market.

## 7.4 SCENARIO 2A

This scenario's driving force is the government's environmental concern, both for the country's sustainable well beings and pressure from international society. No particular fuel efficiency regulations are issued in this case.

### 7.4.1 TAKING OFF

Coal energy plants are one of the major polluting sources in China. It not only possesses current environment problems, also remain obstacles for electric vehicles' wide diffusion. For this concern, there is no more expansion of coal-burning energy plants. New plants to generate electricity will have sustainable energy input, which in a sense slow down development demand for energy. In the short term, there might be a shortage of electricity, and its price will rise due to insufficient supply. Sales of e-bikes and e-scooters, slightly decline for the first time.

Although the general public is essential and ultimate target group to solve environmental problems through EV, however, in this case it is almost impossible to achieve its diffusion at the beginning. The initial consumers are public transport system (e.g. bus, taxi) and public sectors. Such fleets demonstration serves two purposes, one is to gradually crash obstacles for EV's diffusion and perfect infrastructure it requires, the other is to advertise this way to increase public acceptance during this process.

Because of the expensive electricity, manufactures postponed their schedule of introducing BEV, and types of electricity dependent vehicles. Instead, HEV and FCV are encouraged to deal with environmental problem of the city. For the time being, oil-gasoline FCV win favorability because of its high energy efficiency and low initial capital cost. As there are no strong incentives for manufactures to engage in R&D activities, the government has to invest research fund or have tax reduction to encourage carmakers. However, as electricity is expected to become clean in the future, research for BEV is not totally held suspended.

Beijing, as a representative of local government, who implement horizontal pattern in industry administration, is more used to develop flourished niche market for innovation activities. Limited models of FCV were introduced to the public transport system and public sectors. At the same time, regulations in favor of R&D activities of ZEV were implemented. Market share of oil-gasoline FCV in Beijing is much lower than that of Shanghai. They have put more attention to development of niche market. However, the lack of clear articulation and coordination obscure the particular end-points for the transformation, compounding uncertainty over appropriate governance measures.



Shanghai's local government as a typical vertical administered authority, has a closer relationship with conglomerated industries. The city has history of cooperation with auto industry, which is willing to invest initial capital to facilitate relevant program. Thus, infrastructure construction, mass production and intensive R&D cooperation are likely to take place here faster than any other place in China. Because of rising price of electricity, schedule for BEV were suspended. And incentives for FCV were provided by the central government, together with local government's concern for environment. Oil-gasoline FCVs were introduced on a large scale. Various models were soon introduced to the general public. With the efforts of both local government and manufactures, infrastructure obstacles were removed as soon as possible. Market share of FCV have risen dramatically during this period. However, the selection pressures themselves will probably represent the best focus for governance strategies: working with the 'back-end' of regulatory systems (regulations, taxes, and so on) to try to create a selection environment that induces the through an alignment of smaller changes shaped by existing capabilities and guided by prevailing expectations (Smith et al., 2005).

#### 7.4.2 BREAK THROUGH

As design and construction of sustainable energy plants have gained experience during this period, plans for transformation of old polluting energy plants come to table. This trend is towards decentralization of energy supply instead of the former centralized model. Solar energy plants are largely diffused in cities, while hydro power and wind turbine are mainly adopted in remote region and sea coastal area.

A gradual increase in diffusion of FCV among the general public has taken place, due to completeness of complementary goods (e.g. refueling infrastructure, maintenance network). As no obvious incentives for the public to adopt FCVs immediately, they are considered only when its overall attributes equal with conventional vehicle. A steady infiltration of FCV is taking place.

An optimistic perception of development of BEV is obtained, due to clean energy diffusion. BEV is preferred by the government because of its low life cycle cost and its mechanism being free of oil. Due to its slow progress during the past decade, BEV's performance has not been improved greatly at the beginning. Subsidies have to be assigned to compete with the matured market of gasoline FCV and conventional vehicles. However, manufactures are enthusiastic about BEV's market, for its low maintenance cost and oil free nature. An intensive competition is about to go for first mass production of BEV as soon as possible.

Beijing city as the early follower for BEV through subsidy and policy measures, efforts for BEV's R&D activities have gained achievements in BEV's performance. Because of the initial investment of the local government, they would like to see their efforts paid off. These firms are not likely to be easily purchased by other large carmakers without confronting with local authority for their approval.

Whereas in Shanghai, as penetration of gasoline FCV becomes deeper and deeper, this market is well accepted by both carmakers and the users. Infrastructure (e.g. charging stations) for BEV is far from

competent, which fails to win the heart of the public. However, carmakers are more sensitive about the market's potential, and they are also motivated to change the current situation of being oil dependent. On the other hand, as large sunk costs are involved in FCV models, carmakers intend to mitigate loss during this transition.

### 7.4.3 STABILIZATION

Oil consumption arises in transport sector, though vehicle energy efficiency keeps improving, the number of vehicle stock steadily rise too. Transformation of polluting energy plants and decentralization of energy generation is about to complete throughout China. This trend is in favor of both the government and the public's interests, a thorough transition from FCV to BEV is taking place.

Expansion of grid and charging infrastructure for BEV are required to meet the need for this transition. Battery recycling industry has gained attention for recycling efficiency and safety issue on metal disposal.

Cleaner energy source has removed ambiguous attitudes towards large introduction of BEV. However, gasoline FCV still has supporters for its easier and faster refueling process. Thus, auto market is shared by both BEV and FCV.

BEV's market infiltration in Beijing have been faster than that of Shanghai, since Beijing's auto market haven't embrace gasoline FCV at the beginning. Considering BEV's infrastructure is much different from that of FCV, the government is fully engaged in infrastructure construction instead of hesitation for infrastructure transformation.

Purchasing BEV's technology and setting up production lines for new models has cost large sum of sunk cost, and manufacture in Shanghai has to rely on old FCV models to gain profits. Infrastructure construction work is largely dependent on the local government, since auto industry lack of capital investment at this period. Because of slow rate of completion of charging infrastructure and tepid attitudes of the carmakers, market share of BEV at the beginning is relatively slow. However, as infrastructure completion and recovery of auto industry, BEV starts to win its favorability among the users.

## 7.5 SCENARIO 2B

This scenario's driving force is the government's environmental concern, both for the country's sustainable well beings and pressure from international society. A more strict fuel efficiency regulation is issued in this case.

### 7.5.1 TAKING OFF

Coal energy plants are one of the major polluting sources in China. It not only possesses current environment problems, also remain obstacles for electric vehicles' wide diffusion. There is no more expansion of coal-burning energy plants. New plants to generate electricity will have sustainable

energy input, which in a sense slow down development demand for energy. In the short term, there might be a shortage of electricity, and its price will rise due to insufficient supply. Sales of e-bikes and e-scooters, slightly decline for the first time. On the other hand, China doubles its efforts for alternative energy searching (e.g. natural gas).

Although the general public is essential and ultimate target group to solve environmental problems through EV, however, in this case it is almost impossible to achieve its diffusion at the beginning. The initial consumers are public transport system (e.g. bus, taxi) and public sectors. Such fleets demonstration serves two purposes, one is to gradually crash obstacles for EV's diffusion and perfect infrastructure it requires, the other is to obtain public acceptance during this process.

Because of high price for electricity, manufactures postponed their schedule of introducing BEV, and types of electricity dependent vehicles. Instead, HEV and FCV are encouraged to deal with environmental problem of the city. For the time being, oil-gasoline FCV as well as NG (small)-hydrogen and NG-methanol fuel chains wins favorability because of its high energy efficiency and low initial capital cost.

Fuel efficiency regulations are issued to set higher emission standards. This newly issued regulation motivates carmakers to a large extent. Domestic carmakers search way to improve their technology level of energy efficiency. More intensive cooperation between international leader firms and domestic ones can be expected. This regulation also provides incentives for foreign carmakers to transfer their leading efficiency technology. FCV is the next generation product the auto industry focus on.

As vehicles of low fuel efficiency are forbidden on road, some models of low price also withdraw from the market, which has restrained sales of auto industry greatly. More people go back to public transport, which in return has been improved by the local government under pressure.

Beijing, as a representative of local government, who implement horizontal pattern in industry administration, is more used to develop flourished niche market for innovation activities. Here, governance measures fostering movement towards sustainability will be more intense and explicit than in scenario 2A. Limited models of FCV were introduced to the public transport system and public sectors. On-road vehicle fuel efficiency has greatly improved. At the same time, regulations in favor of R&D activities of ZEV were implemented. Market share of oil-gasoline FCV in Beijing is lower than that of Shanghai. They have put more attention to development of niche market. Some small carmakers which have benefited mainly by high-emit vehicles of low price bankrupt to a large extent in this period.

Shanghai's local government as a typical vertical administered authority, has a closer relationship with conglomerated industries. The city has history of cooperation with auto industry, which is willing to invest initial capital to facilitate relevant program. Thus, infrastructure construction, mass production

and intensive R&D cooperation are likely to take place here faster than any other place in China. Because of rising price of electricity, schedule for BEV were suspended. Fuel efficiency regulations provide incentives for carmakers to speed up process for introducing new products. Small carmakers mainly focus on how to improve their technology for higher fuel efficiency, while larger firms focus on fuel cell vehicles that do not depend on electricity. Various models of high fuel efficiency were soon introduced to the general public. With the efforts of both local government and manufactures, infrastructure obstacles were removed as soon as possible. Market share of FCV have risen greatly during this period. However, given that innovative activity is shaped from within the regime itself, it will tend to be steered by the interests, values, cognitive structures and problem- solving routines prevailing in the incumbent regime (Smith et al., 2005).

### 7.5.2 BREAK THROUGH

As design and construction of sustainable energy plants have gained experience during this period, plans for transformation of old polluting energy plants come to table. This trend is towards decentralization of energy supply instead of the former centralized model. Solar energy plants are largely diffused in cities, while hydro power and wind turbine are mainly adopted in remote region and sea coastal area. Reservation of natural gas has been found in coastal area, China's energy proportion for NG is expanded.

A gradual increase in diffusion of FCV among the general public has taken place, due to completeness of complementary goods (e.g. refueling infrastructure, maintenance network). Vehicles of low fuel efficiency have been eliminated from the road, technology for new generation are mature enough to be mass produced to lower price. The auto market overall has recovered. And a steady infiltration of FCV is taking place.

Conventional vehicles with high fuel efficiency and low emitted FCV and HEV have been introduced on a large scale. The next target of the auto industry is ZEV. An optimistic perception of development of BEV is obtained, due to clean energy diffusion. BEV is preferred by the government because of its low life cycle cost and its mechanism being free of oil. Due to its slow progress during the past decade, BEV's performance has not been improved greatly. Subsidies have to be assigned to compete with the matured market of conventional vehicles. As well as NG-based FCV also draw attention for its low life cycle cost, the nation set target for promoting its introduction. However, manufactures are enthusiastic about these markets, for their low maintenance cost and oil free nature. An intensive competition is about to go for mass production of BEV as soon as possible.

As vehicles' price going down, although emission standards are strict, size of vehicle stock keeps increasing, cities feel the pressure of traffic congestion and environment contamination. Regulations following the leading emission control standards will have to be established to rule this situation

Beijing, through policy measure and subsidy of the government, efforts for high fuel efficiency have gained achievements in vehicles' performance. BEV's and NG based FCV has gradually shown their

promising potential during the last decade, and their attributes have also been improved greatly. Because of the initial investment of the local government, they would like to see their efforts paid off. These firms are not likely to be easily purchased by other large carmakers without confronting with local authority for their approval.

Car manufactures that have chosen to improve fuel efficiency on conventional vehicles may have to face a dead-end situation. They might be forced to seek solution on EV. On the other hand, some early starters would receive their pay off and have a better position than the others. FCV has already gained a market share, while BEVs come on table again. Infrastructure (e.g. charging stations) for BEV is far from competent, which fails to win the heart of the public. However, carmakers are more sensitive about the market, they are also motivated to change the current situation of lagging behind. On the other hand, as large sunk costs are involved in FCV models, carmakers who have already have their stakes on FCV are likely to further improve their products on established models.

### 7.5.3 STABILIZATION

Transformation of polluting energy plants and decentralization of energy generation is about to complete throughout China. This trend is in favor of both the government and the public's interests, a thorough transition from conventional vehicle to electric vehicles is taking place.

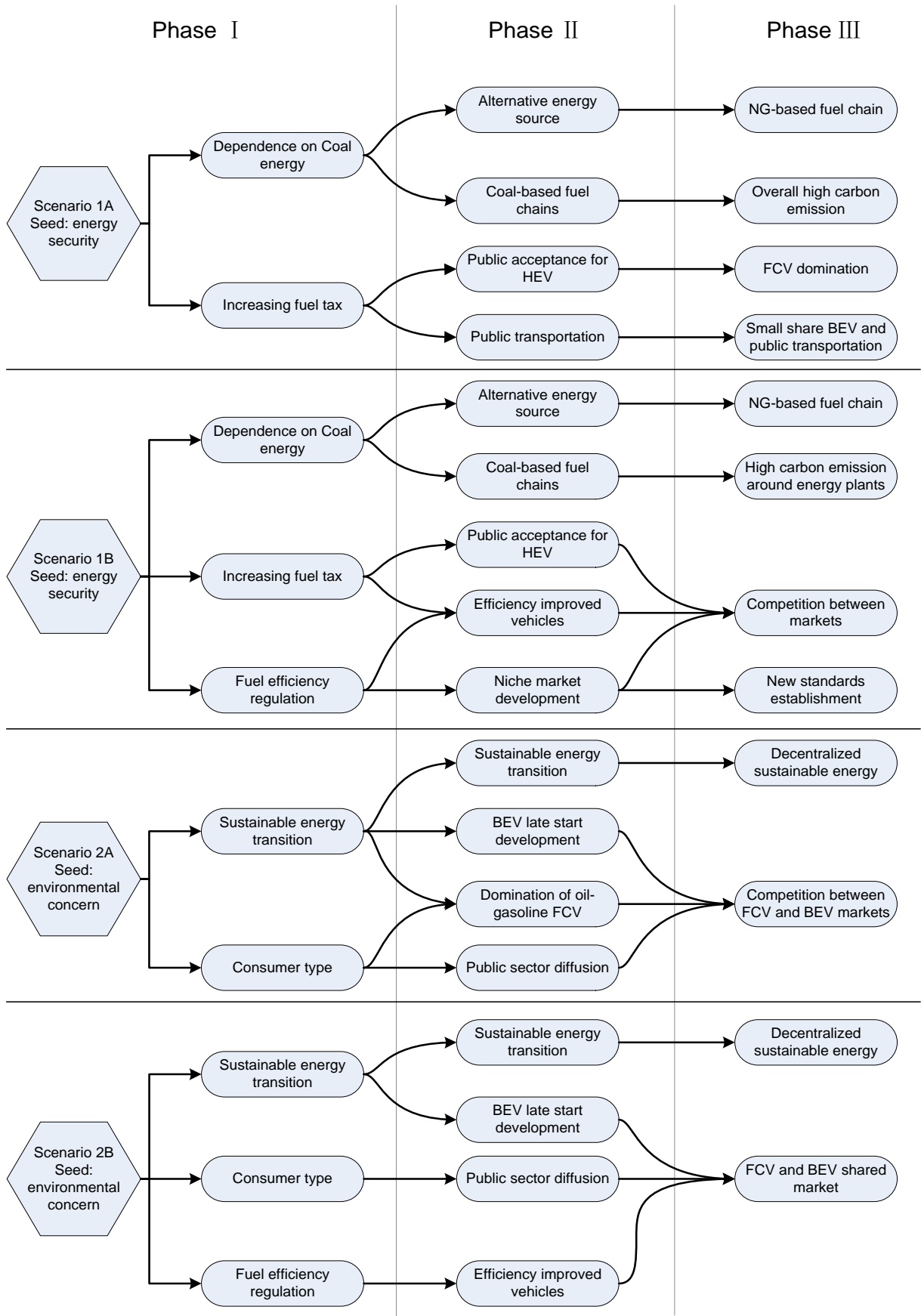
Conventional vehicles only have limited share of the market, while FCV and BEV have gained a large proportion. Since FCV has longer history, BEV is relatively new, thus its diffusion is not as wide as FCV.

Expansion of grid and charging infrastructure for BEV are required to meet the need for this transition. Battery recycling industry has become the focus, which gained attention for recycling efficiency and safety issue on metal disposal. Cleaner energy source has removed ambiguous attitudes towards large introduction of BEV. However, FCVs still has supporters for its easier and faster refueling process.

In Beijing, niche market has grown into a main stream market. These entrepreneurial firms have either grown big or purchased by larger firm for their leading technology. Government administration has reshaped itself in this process gradually from horizontal to more vertical pattern.

In Shanghai, competition between BEV and FCV has just begun. FCV mainly represent conglomerates as early adopters of fuel cell vehicles, which now has grown fully fledged. While carmakers devote in BEV represent new entrepreneurs and firm who have lagged behind by period spent on improvement and expansion of conventional vehicles.

## 7.6 SUMMARY



#### FIGURE 19 SCENARIO 1A, 1B, 2A AND 2B

To compare different scenarios, one can notice that different driving forces are responsible for the major differences in scenarios. Since the initial objectives are different, the whole situations are sent on various trajectories. Along the pathway, government and regime actors will try to achieve equilibrium between many important criteria, however, as the major driving force remain on the priority list, it will still make difference in the final result. Usually, no single driving force could help to facilitate a transition thoroughly, that means, combination of multiple purposes exist in a particular action to initiate changes. Nonetheless, these driving forces are not from the same level and priority, they are graded with different importance. That is to say, there is always one dominant driving force, and even, sometimes others only serve as justification for the main purpose (State Statistical Bureau of China, 2007). On the other hand, a combined way of looking at these scenarios is more realistic, which I believe will achieve better effects while analyzing and generating recommendations.

With the seed of energy security, they all own different degrees of pollution in the end (see figure 19). For scenario 1A, as carbon-based energy is still widely diffused, an overall high carbon emission is inevitable. Whereas in the 1B, as the fuel efficiency regulation tend to push the pollution link along the fuel chain away from the city, regions around energy plants will have to suffer the most from environment problems.

The major difference for scenarios 1A and 1B is the share of auto market in the end. With a pressing fuel efficiency regulations while any type of electric vehicle is not ready to mass produced, the carmakers tend to improve their existing models, which involve sunk cost for conventional vehicles. This capital investment will probably serve as an obstacle in the following development of electric vehicles. And some small carmakers are even crashed over by the overwhelming change. However, to abandon the old concepts for auto designing has a potential advantage, which is to develop whole new idea about future electric vehicle without practical concern to reduce transition loss in the process. Thus, in scenario 1B, a totally new niche market is nurtured, which in the end become a strong competitor of the conventional auto market. Besides that, a well established public transport system has been set up in Beijing, which alleviates traffic pressure to a large extent. However, on the other hand, it reduces the driving force for development of EV's market and thus loses opportunities of being leaders in this field.

With the seed of environmental problems, scenarios 2A and 2B all experience transition towards sustainable energy and result in a decentralized form of energy supply. This is a painful process, since the growing demand is not totally met at the beginning and R&D for BEV was once suspended, which might be responsible for the late-start development of BEV. However, efforts were paid off in the end, and the much cleaner and more sustainable scenarios are obtained finally.

The major difference resides in scenarios 2A and 2B is different situation and market share in the auto market. Since FCV has become dominant in midterm of scenario 2A, the BEV in the end is still a new

comer who tries to compete for the market. However, as the driving force for BEV's development is not institutional one (while decentralized sustainable energy supply is achieved) but the market. BEV is considered as a strong competitor in the market. However, in scenario 2B, FCV has not achieved dominance in the market due to hesitation for improvement of conventional vehicles. The main competition is still between the electric vehicle market and the conventional one. But with obstacles, such as polluting energy plants, insufficient complementary goods and economical concern are being removed, a total changeover of the auto market will take place.



## 8 CONCLUSION AND DISCUSSION

At the beginning of this report, I proposed research question as: ***What are the scenarios for electric vehicles' transition in China?*** In this chapter, this question will be answered based on study and analysis made in previous chapters through providing conclusion and discussion of the sub-questions, which decompose the main question into different dimensions.

### 8.1 THEORETICAL CONCLUSION AND DISCUSSION

As I have proposed the theoretical questions as: *To what extent do transition theories and methodologies apply to China?* The answer I have for this question is mainly from two sources. Case study of e-bike and the overall analysis of electric vehicle, both provide insights into this question.

Analysis of the transition theories were conducted in Chapter 2. At the heart of the transition theory are three 'levels' and the interactions between them (the multi-level perspective; Kemp, Rip and Schot 2001). MLP practically use the perspective of evolutionary economics, sociology, history, and technology and innovation research. MLP is divided into three levels of analysis and heuristic understanding of system innovation. Essentially, the theories are broad and robust enough to cope with varieties of situations, in which China's context included.

However, when it comes the methodologies based on transitions theories, minor adjustments can be suggested. Not thorough general models are generated in the analysis due to the scope of this research, instead some partial conclusions are made based on concrete facts and grounded assumptions.

For socio-technical scenarios, several phases have been distinguished (Rotmans et al., 2001; Geels, 2005). In the first phase, novelties emerge in niches in the context of existing regime and landscape developments. Actors support the niche, hoping that novelties will eventually be used in the regime or even replace it. This is not easy, because the existing regime is entrenched in many ways. In the second phase, the novelty is used in small market niches, which provide resources for technical specialisation. The third phase is characterised by a breakthrough of the new technology, wide diffusion and competition with the established regime. This is basically true under a rather stable economical and technological circumstance, however, which is different from what I have seen in the rise of electric bikes. Ever since the Chinese economic reform in 1978, there has been massive changes in Chinese society, for instance, the country was opened to foreign investment for the first time since the Kuomintang era. In that case, changes in landscape level provided a very dynamic environment for regime transformation, which is not usually seen, as landscape development is presumably to be slow. The regime level interact with the landscape level intensively, and much more 'window of opportunities' emerged than it was expected. Under such circumstances, many socio-technical transitions did not try to entrench silently within the orders, but take advantage of the

dynamic environment rise altogether with it. This is also a possible reason for the fast pace of decision making process in China, which is largely discussed in recent years. This suggests an accelerated transition model for China, at least in the several decades after 1980s. Although the length of this period cannot be identified for now, the question remains that how long this dynamic situation and its post-effects will last. However, traditional transitions theories cannot be applied to China in the dynamic period without consideration of the phenomenon described above. And for the e-bike case alone, another factor also contributed, that is the high maturity level of this applied technology. This is a widely applicable contributor in many technological transitions in China due to the late start China's development. However, in the future less such transitions will be expected, and more high-tech niches are likely to emerge like the case of electric-vehicle. Also, the very dynamic landscape level is expected to slow down in the future, thus 'windows of opportunities' will be shutting down, which will possibly result in slower pace of decision making process. Though close examinations of specific cases can be benefited from this study, more researches are called for to formulate a thorough understanding for STSc's application in China.

Quasi-evolutionary model of socio-technical transition is adopted in this research for its clear structure and articulated aim 'to distinguish more clearly between different elements in the context for regime transition: the articulation of selection pressures and the adaptive capacity available to facilitate regime transformation' (Smith et al., 2005). However, criticism of this method is also discussed by some researchers as 'every transition becomes coordinated at some point through the alignment of visions and activities of different groups' (Geels, Schot, 2007). This vision is shared especially in this research under the circumstances of China. Top down policy plays a big role here in China, which is clearly shown in the case of electrical two wheels. From the historical perspective, this tradition has shaped Chinese society for thousands of years, so it is not likely to change easily. When a huge transition is expected in China, the government is almost always involved for its centralized role to the society. Thus, I propose a model with more focus on the coordinated response side of the axis to adapt to the situation of China. Although these situations are given and considered in this model, this shift in focus will help to specify typology or patterns applicable to China. This may even introduce new dimensions to describe socio-technical regime transformation, thus a new model. This conclusion may sound totally new to some previous research as a critique for quasi-evolutionary model that 'no transition is planned and coordinated "from the outset"' (Geels, Schot, 2007). However, the Chinese government officially claimed 'centrally planned economies', which is evidenced in many other cases. For instance, the establishment of 'technology parks' in Beijing, namely, ZhongGuanCun Science Park (ZGC), where governments promote technology parks as vehicles of technology transfer and regional development. Contrary to what Scott (1992) has noted that it is difficult to identify the emergence of a cluster before it occurs. Attempts have been made intentionally by China to learn from some role models in the development process, and ZGC was a prototype of a Chinese model of technology transfer and diffusion, inspired by the success of Silicon Valley in California. In the early of 1980s China's central government recognize the commercial values of scientific and technological

knowledge and managed to restructure the existing research institutions by establishing some encouraging policies. Thus, this characteristic should be interpreted into a more precise model designed for China in the further research.

In the proposed new model, another finding recommended to be considered is the regional differences, which play an important role in my analysis. The Local authority would tend to follow the direction that the central government pointed out, since strong dependence of local governments exists. On the other hand, policy interpretation and implement of local authorities are important. When central government doesn't give direct instructions, or show clear intentions, local governments would play key roles regarding policy making and implementation. Addition to that it is almost impossible for the central government to map out the pathway for each region of the country, policy interpretation became crucial. And it is also recommended to consider varied conditions of different region, an extreme example stands when it relates with the fact that large gap between cosmopolitan cities and poor rural areas. And more common situations of it are the differentiated administration patterns of local authorities as in our cases Beijing and Shanghai, due to their different development histories.

## 8.2 EMPIRICAL CONCLUSION AND DISCUSSION

The Empirical question I have in this research is:

- *Who are the actors that possess significant influence in the transition of electric vehicle in China?*
- *How do actors, interact in the present socio-technical system in China with respect to the case of EV's (and within the case of electric bikes and scooters)?*

The he answer I have for this question is mainly generated from chapter 4, 5 and 6, where each level of MLP (multi-level perspective) model is closely look into. Actors in figure 13 are shown as essential stakeholders in this analysis, where local government-carmaker relationship and carmaker-consumer relationship are examined closely. This is also one of the results of the case study of e-bike's development in China, and these actors are also actively involved in that particular case.

### LOCAL GOVERNMENT-INDUSTRY RELATIONSHIP

For local government, its administration pattern towards industries have been classified as horizontal and vertical pattern, Beijing and Shanghai are illustrated as representatives respectively. At the same time, competitiveness between local governments exist which actively influence the way they deal with different industries. For auto industry, especially international carmakers, barriers and motivations are ruled out. Market pressure and legal obstacles push and pull automakers' position and attitudes constantly, which result in a dynamic situation.

### CARMAKER-CONSUMER RELATIONSHIP

For consumers, an interview is made to evaluate the public's attitudes towards conventional vehicle and electric vehicle. Although the number of subjects is not enough to draw significant conclusion on electric vehicles' public acceptance, some general characteristics can be obvious observed as foundation especially comparing to another interview conducted in the US. For carmakers, intensive competition of the auto market has formulated a series of cognitive rules to follow in model varieties, expansion of production lines and incremental improvements.

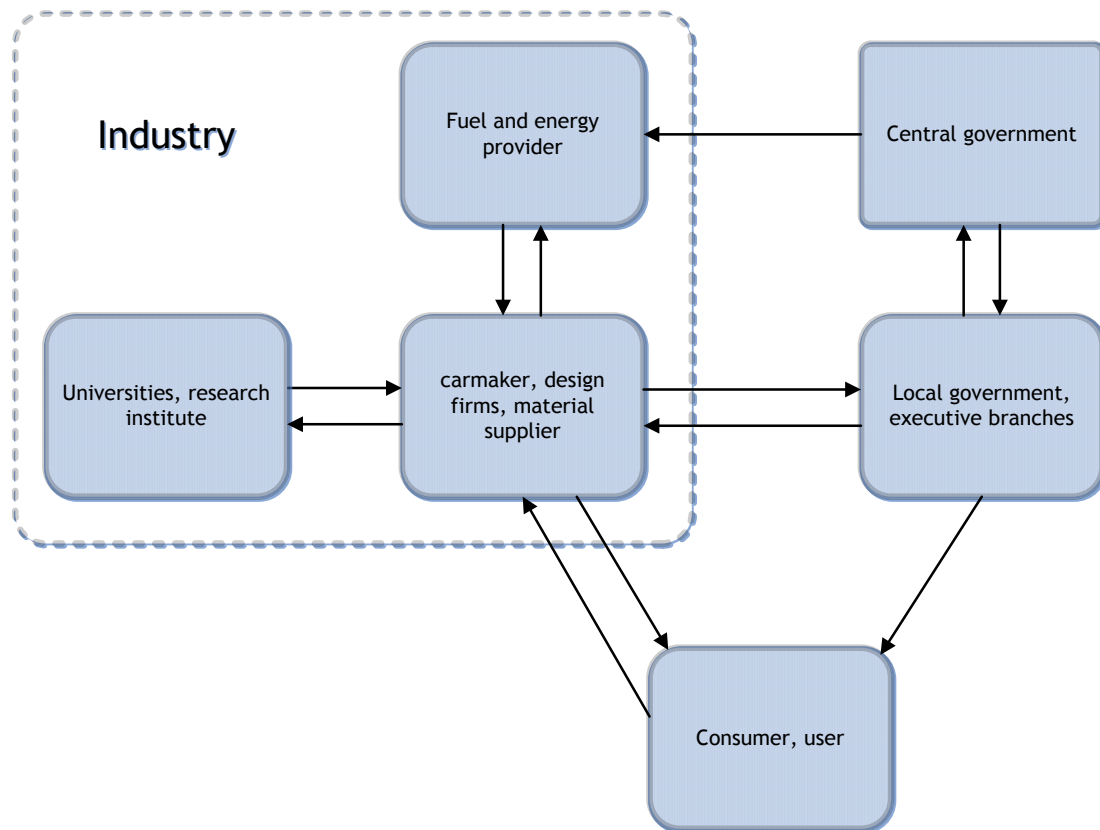


Figure 13 network of government, users and industry

Local government-carmaker relationship and consumer-carmaker relationship are identified as important and illustrated precisely in Chapter 5. However, there are still other relationships worth looking into closely in the future analysis, which are not conducted due to the scope of this study.

Central-local government relationship. With stress on top-down structure of administration system in China, relationship between central government and local authority is a significant factor in analyzing policy making and implementing. On the other hand, it is also important when an attempt is made to look into local government's motivations more deeply. However, it is also a difficulty research, because lack of a proper measure to examine this subtle relationship, within which various factors (e.g. political complexes) play roles.

Research institutes-carmaker relationship. To examine technology advents closely enough to trace its path and predict its direction is also noteworthy, though considering its dynamic nature. For this

purpose, relationship between research institute and carmaker is not to be ignored. Structure of institutes and industries will have significant influence on how knowledge is obtained, and forms of cooperation will affect how knowledge is transferred and diffused.

### 8.3 PRESCRIPTIVE CONCLUSION AND DISCUSSION

The most important sub-question among the three is probably the *prescriptive questions*: *What recommendation can be given to China's government on the development of EV based on this study and the socio-technical scenarios developed?* Answer for this question is based on chapter 7, where socio-technical scenarios are introduced and the previous studies are synthesized.

Development of electric vehicles in China is considered a solution for energy and environment problems. In the socio-technical scenarios in our analysis, Scenario 1 driven by energy security and Scenario 2 driven by environmental concern all end with a satisfactory outcome considering their initial intentions, that means they all solve their targeting problematic issues. From this perspective, promotion of electric vehicles' development in China is rewarding and should be recommended. However, some important implications have been derived from the scenarios, which are not to be ignored in case to achieve a sustainable future for China and the world.

#### ENVIRONMENT SUSTAINABILITY COMES FIRST

It is obvious from comparison between scenario 1 (1A &1B) and scenario 2 (2A &2B), that the environmental problems ended differently in the given time frame. Environment problems as driving force in Scenario 2, emerge at the very beginning, however, it also reveals itself in a later stage in scenario 1, which results from pressure not only of environmental issues, but also transportation difficulty and energy security. From another perspective, improving environmental sustainability helps solving other pressing issues as well.

It is recommended to realize it through three steps. The first one is to stop adding polluting plants, this will no doubt adding burden of energy supply and cause problems in the short term, e.g. rising electricity and heat price. However, this painstaking process will give rise to pressure of sustainable energy development, which will help promoting and accelerating process of sustainability realization. In the following step, new sustainable plants should be added mainly to rural regions, where abundant sustainable resource resides. Knowledge and technology breakthrough will be obtained through accumulation of experience, and economy scale will bring down the price of sustainable energy. The third step includes transformation of old polluting plants, possibly through decentralization of energy supply, which is a controversial idea comparing to China's centralized power system. Nonetheless, it is not unprecedented. This idea has been suggested and implemented in some rural electricity program, which is performed under pressure of poor existing infrastructure, however, receive unexpected benefits in the process.

#### PUBLIC TRANSPORTATION AS AN OPTION

As scenario 1A has shown, a tepid auto market comes together with a rather flourished public transport system. With the fact that promotion of electric vehicles alone will be facing many problems and an important one of them is the transportation pressure, especially in China, a country with huge population. This phenomenon suggests that public transportation can be adopted as an option to help alleviating mobility pressure of the cities in the process of electric vehicles' transition. This scenario contradicts with many developing countries' will to take spots in global auto market by investing and increasing domestic vehicle stock. However, it is coincide with some analysts' opinion that public transportation should be developed as a prior option in transport sector to achieve sustainable development for developing countries instead of following the old routes of industrialized countries. Especially according to some population simulation and prediction, China's general population will peak in 2020 and gradually decline in the following decades, that means, cosmopolitan cities as Beijing and Shanghai will stop sprawling in the near future. Further completion focus on infrastructure perfection in the inner city is to be expected, and it can serve as a complementing solution along with electric vehicles' introduction. However, if traffic pressure and other problems are over reduced, it will also result in insufficient motivation for development of EV's market. Thus, focusing on developing public transportation has to be carefully considered as an option.

Yet another strategy has been adopted in scenario 2A and 2B that public transportation (e.g. bus, taxi) together with public sectors will be the initial users of electric vehicle. First, it resolves potential users' worries of lack of complementary facilities of EV and also provides them with firsthand experience of using them. Secondly, it can reduce the cost of building new facilities. Also, if introduction of EV has to be postponed it is also safer to make an attempt like this first. Thirdly, it helps accumulating experience of building and running electricity charging station, which is important in a country like China, it's possible some special actions have to be taken to prevent theft and vandalism.

In the area of developing public transportation, Beijing has some experience to share. Beijing has implemented several public transportation projects and regulations, which have achieved positive effects in alleviating ever growing transportation pressure. These actions include complementing transport system and increasing accessibility through expanding and intensifying transport network, and multiplying approaches of connecting within the network e.g. metro, bus and tram. At the same time certain subsidies provided by the transport sector are introduced to bring down the price of public transportation. And innovative approaches have been introduced e.g. the exclusive bus route on land that creates 'metro without rails' to alleviate traffic congestion. These experiences have provided insights and knowledge, which can be enlightening in relative policy's formulation and implementation throughout China.

#### BE CAREFUL WITH FUEL EFFICIENCY REGULATIONS

No doubt fuel efficiency regulation will expedite the process of technology accumulation and transfer, and improve air condition of the cities in the short term. However, from a long orientated point of view, the ever rising bar of fuel efficiency tends to increase competitiveness in the conventional

vehicle regime, which is well established and is dominating the auto market right now. This intensive competition inclines to keep carmakers focus on incremental improvement instead of long orientation, which serves as obstacle to the transition of electric vehicle. Because market competition forces carmakers to make decision to not to lose market share at hand, which is obviously in the interests of short term benefits but also possibly an inevitable step to help their brand sustain. At the same time, limited resources are provided inside the regime, which restrain the scope of automakers future developments, sides have to be taken between the conventional and the innovative under such stressful circumstances. On the other hand, another possible outcome of a pressing regulation is that it discourages development of small carmakers, even causes mass bankruptcy among mainly domestic carmakers, which are not competent enough to survive in a very intensive environment. This is also the main reason the policy-makers have been hesitating about fuel efficiency policy. Besides, these small automakers are more flexible, who have the potential roles to be the incubus of innovation products.

Furthermore, the regulations may be used as a tool for vehicle stock controlling and city environment issue. For the vehicle stock, through this measure, it is likely to be effective for the meantime that it will remain stable for a while as strict regulations constrain the available amount of vehicles on road. However, as incremental technology catch up with the targeted standards. Increasing on-road vehicles will contribute no less air pollution than the former mode, since the total amount of vehicle stocks start to get higher again. For the city's environment concern, it is also an effective tool to solve this problem. However, in the comparison of Scenario 1A and 1B, in which energy plants transformation have not taken place before fuel cell vehicles' introduction, a stressful environmental policy will possibly cause serious consequence in polluting city's outskirts and rural region, since the selection of fuel chains have main concern for the cities' environmental needs under such circumstances.

As Jordan and Lenschow suggest in 2000, the augmentation of regulatory measures with more explicit sustainability objectives, as is now being advocated in the debate over environmental policy integration. Clear objectives, possible negative consequences are essential and imperative to policies' formulation and implementation. In the case of electric vehicles' transition, the governments (policy makers) have to hold clear and constant attitudes towards this alternative technology. Like Köhler (2009) has stated it is necessary to continue to support radical alternative technological niches, even while biofuels and hybrids begin to take off and challenge the ICE regime. Only with sustainability in policy orientation and implementation can China fight against wavering attitudes of the market and achieve sustainable future.

#### TRANSITION MANAGEMENT IS A KEY ROLE

As depicted in scenario 1B, a successful niche market is developed by the joint effort of local governance and external regime, where new standards for electric vehicles come into play instead of extension of conventional vehicles. In this process, transition management is a deliberate attempt to

change the regime according to a consensus guiding vision (so that selection pressures are highly articulated). Transition management is often presented as regime transformation guided principally by negotiation between social actors from beyond the regime (Smith et al., 2005). In this sense it coincides mostly with what is defined as a purposive transition. Key to the transition management project is the greater role afforded to the governments, both in articulating pressure for change, and in providing the resources, capabilities and networks that condition the responses. To bring external regime actively involved in this transition is rewarding to China's governments, since it provides environmental problems a solution and more importantly give the country an opportunity to be successfully entrepreneurial in auto industry. However, it is not easy things to do given the facts in Chapter 3, where battery manufactures of electric two wheels (E2W) are regarded as the major external regime to be considered. The technology gap between EV and E2W are huge, this transition will not be achieved without the help of external group (the governments) to provide important resources, capabilities and networks. For instance, universities and research institutes have to be involved to provide knowledge fulfilling the technological gap, and on the other hand fiscal encouragements have to be concerned to offer incubus against the market in the short term.

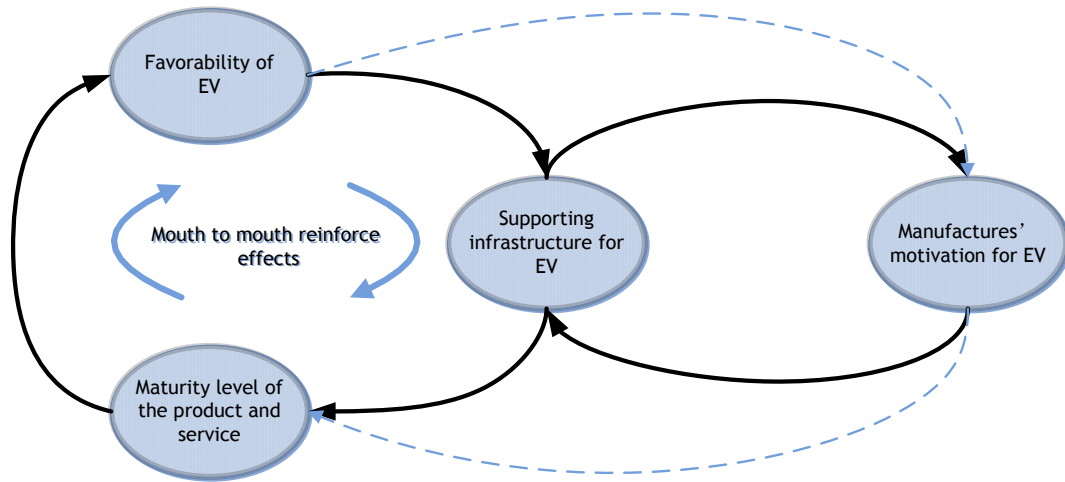
There is another way of providing resources, capabilities and network for the government to facilitate this transition. Although it is difficult to manage a successful transition from electric 2 wheels (E2W) to electric vehicles (EV), or even for it to contribute to EV's development, but once it is succeed the outcome will be quite rewarding. China is using e-bike as stepping stones for development of EV. Except for promising potential of this transition from E2W battery to BEV battery, one cannot afford to ignore the fact that these two types of batteries differ in many ways. In this case a smooth transition should not be expected, but a technology breakthrough of E2W is more likely to impose a significant influence on battery development of BEV. Nonetheless, technology breakthrough of E2W's battery technology is not the only way it can contribute to the development of BEV. As wide spread use of E2W has already taken place in China, we can also see an expanding experimenting ground for BEV. Since the number of E2W in China is increasing, the validity and significance of battery experiments also rises. On the other hand, expectation for E2W's performance keeps rising because of intensive competition, so manufactures are also motivated to improve its relevant attributes, e.g. range, lifetime. However, this situation requires a close cooperation between E2W's manufacture and BEV's designers, or least E2W with a strong ambition and competence of producing EV. On the other hand, this transition can also be relevant in infrastructure's construction. Establishment of E2W's charging infrastructure on road will have several contributions to the development of EV, which is also recommended in Chapter 3.

#### START THE REINFORCING CIRCLE

In previous work, endogenous dynamics have primarily been captured by analyzing the chicken-and-egg problem (McDowall, 2006). This problem describes the reluctance of car manufacturers to introduce alternative fuel vehicles (AFVs) in the absence of supporting



infrastructure, and—similarly—the reluctance of fuel providers to invest in infrastructure when no AFVs are available. And in this study, a public acceptance interview is conducted among the potential users of electric vehicles, another similar dilemma is found out as a reinforcing circle between maturity level of the product and the public's acceptance, see figure. 20.



**FIGURE 20 REINFORCING CIRCLE OF EV**

In the reinforcing circle, it is not imperative to find out which comes first, the chicken or the egg, the important thing is to start circle and make it work. Availability of supporting infrastructure of EV is very important to both manufactures and the public (users), thus it is the starting button of both circles and the whole system. In China, one can expect less institutional resistance from fuel and infrastructure providers, since the biggest and most of them are state-owned. It is recommended for the government to move first in this system, since both manufactures and the public lack a long oriented consideration for a sustainable future, which China's governments hold accountability for the people of China and the environment of the world.

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## APPENDIX

Public acceptance Interviews, which is conducted among the general public audience of *2010 Beijing international automotive exhibition*.

Personal Information: Age 25; Gender: Female; Occupation: white collar

I have a lovely *Smart*, as a university graduation gift from family. I mainly use it for shopping and via work, and I feel it is very easy to use. City's vehicle stocks are now keep increasing, followed by a more crowded roads, fewer and fewer parking spaces, and because of my smart's compact, almost every time I can easily bypass the other larger vehicles and driving into parking spaces, I enjoy it very much. And my little car has very low emissions, and fuel consumption too, the monthly expenditure of petrol for me is always a little bit smaller than others. I really like this car. I heard that electric cars have similar features, and even further. Firstly it is a very avant-garde looking style, very lovely and small, which inspires the drivers the feeling of young at heart; then it is easy to drive, almost no noise; third, from economical concern it's better to use electricity. When this product become more mature, I am sure to buy a small electric car of the German lines, after all, my own smart is of German lines and I have attached feeling for it. The price I expected is similar to that of Smart. But there are still some worries or so to speak confusion, for example, will the fuel station be all equipped with charging device? How are the car battery lifetime, and car battery replacement, its price and level of convenience? So I think it is better to buy it after the related facilities are equipped and technical problems are solved.

Personal Information: Age 50; Gender: Male; Occupation: senior management of the enterprise

I have an exclusive Audi A6 from my company for everyday use. I am considering buying a car for daily use of the similar grade after retirement and maybe occasionally have some short trips. I have rather high requirement for safety and better quality, simpler driving system. The outlook should be prudent and generous, of course, I prefer German made car, after all, I have used Audi for many years, and the brand itself is very reliable to me. I don't know much about the current popularity of electric cars, but I know with respect to the conventional car it is more economical, and probably more environmentally friendly. But I think for now, electric cars is not so much a car as it is but more like a fashionable "toys", the overall design is avant-garde, it may be suitable for young people. People like me prefer business type of car, which is rarely found in the field of electric vehicle, the price of few of them is extremely outrageous. So I think electric vehicle is still a concept, at least now I won't consider buying. And after it is formally released to the market as a car, with a higher level of complementary facilities compared with the corresponding software and hardware service, I might consider it.

Personal Information: Age 45-50; Gender: Female; Occupation: staff of enterprises and institutions



As a daily commuter travel by public transport system, I found that with population growth, it is getting more and more crowded for public transport, especially at rush hour, so I plan to buy an affordable small car. Now I think it is most suitable for small cars in the city, firstly because it's small, so many narrow roads and so many cars it is more convenient and secure to drive a small car; and then the displacement is small, so that when travelling a long distance of low speed it is more fuel efficient. Electric cars, as a new fad among young people I feel its outlook is a bit too exaggerated for me, it is not suitable for people of my age to use. And now the price is a bit too high, compared with the same model car. I heard that electric cars are more economical because it's cheaper to use electricity instead of petrol, I think if the price of the car itself is too expensive, then, the electric car is not economical, and its economy feather has become a pretext. And charging is not easy, you know, we all beat a long queue waiting to charge, and it's at least about two hours, considering that it is not generally inconvenient. So I think the idea itself is a good one, but if you really want to be able to use it in everyday, I think also, there is quite a long time, so I would not consider for this moment.

Personal Information: Age 50; Gender: Male; Occupation: retired

Because I have already retired, and finally have a lot of time to engage in hobbies which I didn't have time before, such as fishing. I will need a car to load fishing tools and brought me to the fishing pool. Family members can usually drive shopping or having short trips. I now want to buy a family use small car, the price cannot be too expensive, about 100-150 thousand yuan, I prefer a smaller auto emission, being economical is very important. When I was working I did not purchase vehicles, I don't know much about the automotive industry and vehicle characteristics particularly, so before buying I need a clearer understanding of the automotive market. But I heard that people generally reflect that Japanese cars are more fuel-efficient, and they have more varieties for small family cars, so I will focus primarily on the Japanese cars. Speaking of electric cars, I don't know much about it, but the electric bikes are often seen on the streets, whether there is anything in common between them, there should be, after all they are all powered by electricity, right? I feel there is almost no noise, and power is acceptable and it's convenient to ride. I have heard other people that daily use of electric bicycles is cheaper than taking a bus, and more convenient. So I think that electric cars would not figure to get much worse. But the only problem is that almost every year they have to change for the battery, and the range of it is not very good, in total it sounds troublesome, because of the charging time is not short enough, so charging is not very convenient, the trip must be planned ahead, or there will be trouble with no battery. Cycling bikes can also be pushed, if it is the car how it can be done. So I am not so at ease about electric vehicles, or so to speak trust it. I will not consider for now, too much worries.

Personal Information: Age 25-30; Gender: Male; Occupation: Auto Sales

Nowadays autos are getting cheaper and cheaper, watching my friends having their own cars, and also it will be much more convenient, for instance, I don't have to step in crowded bus, and weekend

family can go sightseeing, we can decide routes ourselves, it can easily save trouble and I will feel much better, so I decided to buy a sports, with surging power. This will bring much joy to driving experience. Car do not need to be big, after all, not only price will be high but also a lot of running costs, and driving a smaller car will find parking very convenient. Outlook of it must be dynamic, it looks cool. I feel Japanese cars have done a good job in these areas I will prefer their selection. My budget Price is between 15-20 thousand yuan. Electric cars are absolutely not considered, after all I am doing auto sales and have more contact with the car, so comparing the various aspects of the electric car I feel it is a "vase" - showy but useless. Electric vehicle manufacturers promote energy saving in the economic convenience of modern environmental protection, etc. In short a lot of good. But they simply did not say the focus it should be about first battery performance of electric vehicle, the good range they always said, but the battery life of it? Replacement costs? A battery for electric bicycle now cost almost a thousand and it has to be changed less than a year. Car battery needs more and better, more expensive, more difficult to replace. In this case, being economical is impossible and more other problems to come. Thus electric cars cannot be considered.

Personal Information: Age 20-25; Gender: Female; Occupation: Student

Because more and more crowded roads, so if you choose buses and if you happened to have traffic jam you can expect the waiting time is several times of that of driving time, so subway is actually a better choice, but I personally have issues for "underground" I don't feel right being around, so I decided to buy a car for everyday use. I like the shape of mini-cooper and Beetle cars with a retro feeling, but they have relatively high prices, I might choose a similar but more economical model, moderate emission, I do not prefer a powerful car, I hope my car is small and lovely. Because I intend to buy their own first car, I don't have particularly feeling about car brands, so by that time it will carry out a wide range of choices, of course, price and appearance are the most important factor. I really like electric concept car, and I have done a research into relevant fields so maybe I have more understanding in this area. First of all, to replace oil with electricity for our country have considerable strategic importance, because our country is very rich in coal reservation, but oil imports now quite large, so that the country's long-term development is a major constraint, and if the electric car to largely replace conventional car, energy structure of the country will be shifted from oil to coal, it will be a landmark change. But let me buy electric car, some of the problems would be a great obstacle. The first is its low-noise. Low noise has been an arguably strength of it, but personally I do not have a very good eye vision and my personality is not very careful type, if the driving car is too silent then, for me it is not very safe. If manufacturers can design some equipment to address security risks in this regard, I should consider.

Personal Information: Age 40; Gender: Male; Occupation: business manager

Family would like to spend some quality time together, then having some short trip by car seems to be a good choice. Our daily use family car is a business car, travelling would obviously be

inappropriate, so I plan to buy a sport utility vehicle to meet this need. Because of this requirement, the power must be strong, because we cannot guarantee that the places we travel has a good road condition; another requirement is to be spacious, this car can carry enough travel goods, such as ski board or something like this. The most important thing is the quality of the overall car must be assured, this is the most important one, since nobody want any trouble in a not so familiar place. My budget plan for buying around 500,000 yuan sport utility vehicle, the price almost meet my request. I heard that Toyota's vehicles and Chrysler jeep is good, this time I will focus on them. The new energy vehicles, I heard that more about hybrid vehicles, but it seems pure electric cars that are not quite meet my needs, so I haven't given too much attention on that. Hybrid has many advantages. First, when driving low-speed electric drive can be fully used, thus avoiding the use of inadequate fuel at low speeds causing waste and pollution, I think this point is of the greatest significance. After all city vehicles will inevitably encounter a lot of traffic lights make cars traveling between start and stop, if with hybrid, this kind of pollution will be completely eliminated from streets, I feel very good about it. If the hybrid car has met my requirements and the price is not more than the budget too much, I will seriously considering buying it.

Personal Information: Age 40; Gender: Female; Occupation: business woman

I did not plan to buy a car recently, because my family now has a small family car, which is completely sufficient for everyday use and because of its small emission, our expenditure for petrol every month is very economical. So I do not need to add a car, the purchase of a new vehicle not only will increase fuel costs, parking spaces and other problems will follow. Electric car, then tell the truth I do not like it. When talking about electric bicycles, ordinary bike when traveling, because it is driven by human, so they are generally not at particularly fast pace, so if encountering pedestrians, while ringing, is also very easy to stop. But the electric bike is completely different, not only moving fast and quietly, when riding behind the pedestrians, when it is not felt, so there is no way to avoid ahead of time, because of its faster speed itself, the rider is not easy to quickly stop, it will be dangerous. Electric car, this situation would be even more dangerous. If in the car reversing, because of its low noise, even the close passing pedestrians hear horns, but car itself has no engine noise, so the pedestrian is hard to judge in the short term the car besides is in motion, so that I think it's very dangerous. So I think that the advantage of electric vehicles since the matters relative to the conventional for more than a century, the inherent characteristics is contradict to traditional car, it is not so easy to adapt, so at least now I do not like electric cars.

Personal Information: Age 35-40; Gender: Male; Occupation: business people

I have a business sedan, as it has been driven for many years and start to see obvious sign of aging. I intended to buy a new car to replace it. Usually I drive to work and in weekends, holidays and other leisure time the family are using it together. We generally drive in urban area, rarely drove to a place far away from the city, feeling that is too tiresome. My favorite car has to be reliable, and everything

about it has to be mature. It has to be spatial inside. My budget for buying new car is between 200-300 thousand yuan. I am not so interested in a new brand or new models of cars, because I think the design of new technology or new innovations are usually not so perfect, such vehicles will be in the market for some time, through constant improvements will tend to become perfect. Therefore, I will prefer some older models of cars to choose. Electric cars are still a new concept, not so close to new models in the market. So I think if we buy it now, not only the prices are unreasonable, car itself is also at risk, in other words, its ratio of cost and quality is extremely inappropriate. But I still love its design, after all, energy saving and environmental protection are closely linked with everyone, so if the technology is mature, the car is relatively acceptable I will definitely buy it, not for anything else, just for environment's sake.

Personal Information: Age 50; Gender: Male; Occupation: Entrepreneur

My daughter is about to graduate from college soon, and I intend to buy a car for her as a gift, so she can drive it to work in the future. Our family has a business car, the whole family is using it, my family all have their own view about cars, especially my daughter. She always said that the past business cars look too rigid, feeling not very energetic, and that car is too heavy for her and cumbersome drive; further, it is a little large of the car's emission, refueling frequency is too high, too costly. So I want this time to give the child a car that meet her requirements, I see the Beatles look very good on the street, and all aspects should have met her request, and this car is the German original produced, the quality of it is more reliable and assured. Electric car, I was not particularly understanding, so new things, she should be more understanding, maybe she will like it. Well I think for my little girl to drive, simply to drive is the most important, it is also relatively speaking the safest. If electric cars do well in this regard, I would consider. I think electric cars is energy-saving and ideas of environmental protection should be more interested to these young people and their pursuit of things, coupled with the electric car styling and cutting-edge avant-garde concept, I think this is a good choice. Because I do not know very well I think I'll go and discuss with her daughter, if she like it, she can buy it.

Personal Information: Age 25-30; Gender: Female; Occupation: Urban white-collar worker

I plan to buy a compact sports car, as my friends who have cars, on the weekend and holiday, they drive away from the city near or far away, a group of people driving so many cars, I feel excited when thinking about it, so I really want to buy a car to attend. I want to buy a sports car, which looks particularly dynamic and shape to be particularly lovely, so I can show my personality and beauty. Cars do not need to be particularly large, small and cute plus compact, will probably most with me. Power of course has to be sufficient after all, when playing with everyone I don't want to lag behind in this group. As Japan has done great car styling features, and relatively very fuel efficient, so they were my main choices. Electric vehicles, then the fact that it features all I really like, plus low noise, but if I buy a car used in the city, I would certainly choose it. However, because the main purpose of my car is to have fun with my friends while travelling. And now electric vehicle charging station and its capacity

cannot meet the requirements for travelling. Anyway I can't set out ok and have someone pulled it back in the end. So electric cars I will not consider now, if it is equipped with related hardware in fueling stations now, I will consider about it then.

Personal Information: Age 20-30; Gender: Female; Occupation: young professionals

My family has a car, usually my parents drive it to work, in the weekend I drive it for shopping. I daily commute by bus or subway, take the taxi occasionally. Daily mileage is around 50KM. I Intended to in recent years to buy myself a car, the price between 100,000-20,000 yuan. Because usually I like to drive away from the city for short trips, I request that the quality of the car ought to be reliable with sufficient power. I buy things to achieve the highest ratio of quality and cost, so I do not specially care about brands, I will carefully choose before buying. In this year's Beijing auto show I found that almost all automakers have launched their own new energy vehicles, but not the same the focus of their research, among which BYD is about completely electric cars, and major automakers are mainly hybrid electric vehicle, they might not have good scenario for pure electric vehicle. And I, after compare these cars in today's conditions, hybrids are more practical, environmental protection and energy efficiency of it is more realistic. The concept of electric cars is very good, I love it too. Because first of all I am an environmentalist, and therefore environment friendly products I would all like to be involved. But now the hardware will make the scope of action of pure electric cars become very small, often users have to put it home a lot. If I plan to purchase in the recent couple of years, I would choose hybrid cars, and if anything beyond a few years, when the conditions of pure electric vehicles become more mature, I would choose pure electric vehicles.

Personal Information: Age 23; Gender: Female; Occupation: College Student

My family has a compact family car, in holidays or for everyday use, we cannot do without it for work or for fun, or you can say that it is already member of our family. My parents intend to buy me a car after college for daily commute, cost will be around 150 000 yuan. I use small cars for so many years, I found in today's cities, the advantages of small cars are very large too, of course, fuel-efficient for personal aspect, easy access to parking spaces and so on, from broader perspective, it means less vehicle emission, that is, the smaller the more environmental friendly. Overall, the price to the extent permitted, of course, the better the more lovely is, and most important thing is to have quality assurance. Well coming to brands, made in China has more price advantages, Japanese style car may be more cute. Talking about new energy car, as I recently traveled to Guangzhou auto show, so I have some understanding about it. The many advantages of the new types of EV, I think the most vital benefits of our buyers is of course related to its excellent economic and environmental friendly nature. I think it is pure electric vehicles do the best in these features, hybrid vehicles, after all, only a small part of the time while slow driving time will show the above characteristics. Among them I like BYD, and its presentation a little better than the performance described in the cart to the launching of the difference in the world, but also their own brand names, prices still have its advantages. I think if you

buy the electric car, not only have access to benefits of one's own, but also is supported by the state's grand strategy - to reduce dependence on oil. While the pure electric cars are now facility part is not perfect, but a few years after I think the situation will be much improved so I want to buy when the condition is estimated to be much better, if really so, I will buy it.

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<sup>i</sup> Given that there are always niches around it will depend upon the developments within these niches and the interaction between these niches and the regime whether they set things in motion that eventually lead to a transition. In such transitions, we can distinguish two general patterns, viz. (1) technical substitution and (2) broad transformation.

Some examples of patterns and mechanisms are:

- regime pressure creating room for niches (see above);
- regime trying to counter the threat of upcoming niches via various improvements; sailing ship effect after sailing ships countering the threat of upcoming steam ships;
- niche cumulation: niches building further upon each other like 'self-service public transport' developing out of the EV (electric vehicle) niche;
- niche proliferation: niches spreading to other domains (other regimes or geographically);
- hybridisation: the merger of two options (either two niches or a niche with the regime) to create something new, e.g. the merger of the EV and the internal combustion engine car into the hybrid electric vehicle (HEV);
- forking: the opposite from hybridisation, i.e. the split of an option into to different concepts like electric vehicles splitting into rail-based and road-based systems;
- new technical developments triggering new societal developments: a new technical option, for instance, may seize the interest of new user groups or make it easier to pursue certain policies;
- emerging new user patterns: some technologies may induce (initially small) groups of users to change their behaviour and these groups may grow under specific circumstances; this may be triggered by a variety of reasons like creating new opportunities, distinction, cost-performance considerations, etc. In transitions, often a combination of such reasons is at work while different reasons may appeal to different sets of users.