Ecological Modernization and Environmental Innovation:

What is the Role of Environmental Regulation?

The Case of California's Zero Emission Bus Regulation

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Joint Actions on Climate Change

8 —10 June 2009

City of Aalborg, Denmark

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ABSTRACT

Technological Environmental innovation (TEI) has been taken to be a critical means to achieve both economic gain and environmental performance at the same time in the Ecological Modernization Theory (EMT). The adoption of EI can not only reduce emissions and the consumption of resources but also improve the eco-efficiency to bring about better competitiveness. This is a double benefit for the environment and corporate businesses. Nevertheless, many factors can hinder the adoption of EI. The purpose of this paper is to investigate the factors conditions that govern the firms to adopt TEI and the role of environmental regulation in stimulating the industry to engage in TEI.

It has been a dominant conception in the EM literature that traditional environmental policy should increasingly be replaced by market-based and voluntary measures, because the Traditional Environmental Regulatory Approach (TERA) are taken as less effective in creating favourable conditions for environmentally sound practices and behaviour than the market-based and voluntary measures. Although incentive-based and voluntary

measures are useful and valuable tools, the success of such approach depends, to a certain extent, on the willingness of firms to commit to TEI and the removal of barriers such as uncertainty, negative externality, spillover problem, information asymmetry. Without the regulatory pressure, when faced with TEI that requires the devotion of more firm resources, firms can easily delay or ignore the adoption of TEI, even if the TEI is profitable in the long run.

The new environmental regulatory approach (NERA) is therefore put forth to better address the issue. The basic rationale underlying NERA is to capitalize on the benefits that environmental regulation can bring in terms of stimulating TEIs, while reducing the negative impacts that traditional C&C regulation has brought in terms of preventing companies from searching for innovative solutions and achieving outstanding environmental performance. This is done by replacing traditional environmental regulations with new environmental regulations that are innovation-oriented, and are properly-designed and implemented with the following regulatory characteristics being taken into account: innovation-orientation, goal-setting, stringency, flexibility, certainty, consistency, innovation-oriented, participatory, capability-enhanced, which carry the potentials to induce the favourable innovation conditions for firm-level TEIs. The NERA

also implies the need for the regulatory component to be mixed with the market-based and voluntary components that offer additional incentives, facilitate innovation capabilities, and change managerial perceptions and receptivity towards technology change. On the one hand, the regulatory component of the NERA guarantees that firms are motivated to continuously search for new TEIs to meet the constantly tightening standards. On the other hand, the incentives and voluntary component facilitates firms to improve various innovation conditions to achieve superior environmental performance.

Key words: Technological Environmental Innovation, Environmental Regulation, New Environmental Regulatory Approach, Ecological Modernization

Ecological Modernization and Environmental Innovation: What Role for Environmental Regulation?

INTRODUCTION

Technological Environmental innovation (TEI) has been taken to be a critical means to achieve both economic gain and environmental performance at the same time in the Ecological Modernization Theory (EMT). The adoption of EI can not only reduce emissions and the consumption of resources but also improve the eco-efficiency to bring about better competitiveness. This is a double benefit for the environment and corporate businesses. Nevertheless, many factors can hinder the adoption of TEI. The purpose of this paper is to investigate the conditions that govern the adoption of TEI and the role that environmental regulation can play in stimulating the industry to engage in TEI.

It has been a dominant conception in the EM literature that traditional environmental policy should increasingly be replaced by market-based and voluntary measures, because the Traditional Environmental Regulatory Approach (TERA) are taken as less effective in creating favourable conditions for environmentally sound practices and behaviour than

the market-based and voluntary measures, because of its adversarial, inflexible, and command-and-control regulatory characteristics. Although incentive-based and voluntary measures are useful and valuable tools, the success of such approach depends, to a certain extent, on the willingness of firms to commit to TEI and the removal of barriers such as uncertainty, negative externality, spillover problem, information asymmetry. Without the regulatory pressure, when faced with TEI that requires the devotion of more firm resources, firms can easily delay or ignore the adoption of TEI, even if the TEI is profitable in the long run.

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innovation-oriented, participatory, capability-enhanced, which carry the potentials to induce the favourable innovation conditions for firm-level TEIs. The NERA also implies the need for the regulatory component to be mixed with the market-based and voluntary components that offer additional incentives, facilitate innovation capabilities, and change managerial perceptions and receptivity towards technology change. On the one hand, the regulatory component of the NERA guarantees that firms are motivated to continuously search for new TEIs to meet the constantly tightening standards. On the other hand, the incentives and voluntary component facilitates firms to improve various innovation conditions to achieve superior environmental performance.

In the following, we will first examine the theoretical relationship between ecological modernization, technological environmental innovation, and environmental regulation. The role of NERA will be outlined. Second, we will use a case study focusing on the Zero Emission Bus (ZBus) Regulation introduced in 2000 in California to illustrate how this regulation resembles the regulatory characteristics of NERA and how it induces the favourable innovation conditions for California transit agencies to start demonstrating the fuel cell buses in the streets.

ECOLOGICAL MODERNIZATION AND TECHNOLOGICAL ENVIRONMENTAL INNOVATION

Emerging in Western Europe in the 1980s, EMT represents a body of social theory that focuses on relations between the environment and the economy (Gouldson and Murphy, 1998; Murphy, 2000; Janicke, 2008). Unlike counter-productivity theories or de-modernization theses, EM basically argues that the most effective and appropriate way to address the ecological crisis is through the continuous process of technical, institutional and social transformation within the framework of the existing capitalist system (Cohen, 1997; Gouldson and Murphy, 1997; Mol, 2001; Mol and Sonnenfeld, 2000). The basic intention behind EM was to link the drive for modernization in the developed market economies and the long-term requirement for a more environmentally friendly development through technological environmental innovation (TEI) that improves environmental efficiency and at the same time yields economic competitiveness as a result of improvement in resource productivity (Gouldson and Murphy, 1998; Janicke, 2008). Hunold and Dryzek (2001: 3-4) observe that: “[The] idea is to solve environmental problems by making capitalism less wasteful and thus more sustainable, while retaining the basic system of capitalist production and consumption. The approach to environmental problem is therefore efficiency-oriented.”

In this article, TEI refers to any new techniques or technologies that have beneficial effects on the environment regardless of whether this effect was the main objective of innovation. However, not all TEIs achieve the desirable EM objective of improving both economic and environmental performance. On the one hand, there are TEIs that provide a huge potential for environmental improvement but incur huge capital investment costs. For instance, the adoption of renewable energy technologies such as fuel cell or solar technologies for companies may be taken as highly environmental friendly in terms of their carbon reduction potential but at the same time creating high financial burden and reducing a company's economic gains. On the other hand, there can be TEIs that create little extra financial burden for the company but yet offer very limited potential for environmental improvement. For instance, the adoption of more energy-efficient technologies may offer a more cost-effective alternative for companies than the renewable options because of the lower capital cost but in return has lesser potential for energy-saving and carbon reduction.

The adoption/diffusion of TEI is determined by economic, firm-internal and contextual factors. Neoclassical economists argue that TEI is more prone to be picked up by companies when the economic benefits associated with the TEI overrides costs and where market failures and barriers, such as negative externality, information asymmetry, technological lock-in, have been removed (Jaffe, Newell and Stavins, 2000). Taking the neo-Schumpeterian perspective, firm-internal and contextual factors that can impact the decision-making of TEI, e.g. bounded rationality, firm capabilities and stakeholder perspectives (Berkout and Gouldson, 2003) have been taken into account in this analysis.

Economic Factors: Economic Incentives

Economic factors refer to those factors that influence TEI decisions based on economic principles and market power. Decisions for or against a TEI option is determined by whether the expected economic benefits outweigh the expected costs of a TEI investment.

One of the major considerations for firm decision-makers with regard to decisions about TEI is economic incentive. From the neoclassical perspective, a profit maximizing firm

will undertake TEI only if the economic benefits of committing in TEI overrides its costs. The incentivizing factors include direct and indirect economic benefits, as well as non-economic benefits that can be translated into economic ones. Direct economic benefits include increased cost-effectiveness and profitability. For instance, the installation of energy-saving technologies for a manufacturing plant may reduce the overall cost of electricity resulting in higher cost-effectiveness. Indirect economic benefits of TEI include improved resource productivity and increased competitive advantage. Another set of non-economic benefits that often associates with conducting TEI, such as improved customer satisfactions, public relations, staff commitment, corporate reputation, etc., may also be translated into economic benefits and be taken into account in the environmental innovation calculus (Porter and Van der Linde, 1995a, 1995b; Gouldson and Murphy, 1998). The higher the economic benefit and the lower the cost of conducting TEI, the bigger the economic incentive for TEI.

Economic benefits can be removed or reduced by market failures and barriers. Negative and positive externalities, failures to promote effective competition, incomplete information and information asymmetry, and technological lock-ins prevent market from providing correct market signals, accessing to complete market information and making

rational decisions on TEI (Jaffe, Newell and Stavins, 2004). For instance, negative externality heightens the opportunities for firms to enjoy the goods and services provided by the environment for free. Firms are better off by not conducting TEI as any effort of doing so does not produce extra benefit for the company but only additional costs. Hence, there are very few incentives for TEI under negative externality. Positive externality, in the form of knowledge and adoption externalities, will encourage less than the expected level of TEI because of spillover effect. Given that late innovators or adopters can always benefit from the knowledge or adoption spillovers of the first-movers, in the form of dynamic increasing returns, it is economically non-beneficial for one to start earlier than later in the absence of any mechanisms to safeguard against knowledge or adoption spillover. Incomplete information prevents rational decision-making of technological choices, creating uncertainties about environmental investments. In some instances, it triggers off underinvestment of TEI. Information asymmetry usually blocks the weaker parties (such as smaller firms) from accessing to the same level of information (pricing and quality) as the stronger ones (most likely the larger firms) and heightens the economic uncertainty and risks of conducting TEI. Finally, technological lock-in increases the resistance to adapting to new technologies. Lock-in implies that the benefits of increasing returns of the existing technologies outweigh the benefits of switching to

superior technologies. The problem is even larger if the shift involves broader social interest. The social resistance to existing technologies introduces further uncertainty of profit return for first movers. Empirical evidence suggests that the absence of non-gasoline infrastructural support accounts for the difficulty in adopting non-gasoline technologies. It explains well why gasoline technologies dominate over non-gasoline counterparts, despite the significant social advantages of competing non-gasoline technologies in the long run (Jaffe, Newell and Stavins, 2004).

Firm Internal Factors: Innovation Capabilities

Apart from economic factors, firm internal factors also affect a firm's decision on TEI. Strategic management literature provides insights into what firm-internal conditions and strategies that determine TEI decisions. Corral (2002, 2003) highlights that a firm's organizational and technological capabilities, strategic alliances and networks of collaboration, will crucially affect its willingness and ultimate decision on technology change. Corral (2002, 2003) regards them as the essential capabilities for a firm to integrate new knowledge into their production processes and products. The more the firm

possesses these capabilities, the higher the potential to diffuse or adopt new environmental technologies.

Organizational capabilities refer to the ability for firms to learn quickly and reshape organizational structures and routines to enable organizational and technological changes in the company. Technological capabilities refer to the extent that the existing production processes are able to adapt to and prepare for transitions towards new technological pathways. This depends upon the nature of physical infrastructures that are available within regulated firms to undergo changes, the technical and technological skills that are available to undergo technological transitions (Gouldson and Murphy, 1998; Kemp, 1997), and the technical tools, such as Life Cycle Analysis, that are available to help firms assess their feasibility to undertake technological change (Corral, 2002, 2003). Strategic alliance refers to the ability of firms to outsource knowledge and to form partnership with suppliers, customers and competitors. Finally, firms need the capability to organize networks of learning and collaboration with universities and public R&D institutions, and to develop relations with other industrial sectors and regulatory institutions and agencies. Corral (2002, 2003) argues that the more the firms acquire these capabilities, the more they are willing and capable of taking part in TEI.

Stakeholder Factors: Stakeholder Attitudes, Norms & Behaviours

This article takes into account the individual, institutional and societal attitudes, norms and behaviours as factors influencing a firm's decision-making on TEI. Evolutionary economics advocates the need to pay attention to the individual characteristics of environmental innovation. Attitudes, norms and behaviours of individuals are considered to be critical determinants in explaining the TEI behavior (Klemmer, Lehr and Lobbe, 1999). Specifically, the attitude of the firm manager on whether to pick up any TEI is related to environmental and economic risks. The higher the perceived environmental risk in association with the firm's existing production practices, the more the willingness of the firm manager to minimize such risk through adopting TEI. In contrast, the higher the perceived economic risk in association with the proposed TEI, the lower the willingness (Corral, 2002, 2003). Further, Neo-Schumpeterian economics argues that technology change is embedded within institutional settings and technological trajectories and thereby institutional norms and behaviours would influence individual decision-making concerning TEI as well. Lastly, a firm's decision-making about technology cannot be disassociated from social and political influence within which the firm is embedded (Kemp, 1997; Berkout and Gouldson, 2003). Firm managers need to attend to attitudes

and norms of societal stakeholders such as customers or regulators. Any TEI which conforms to societal perspectives and norms will be more readily accepted by individual decision-makers because of its potentially higher acceptability and lesser resistance in adoption.

THE ROLE OF ENVIRONMENTAL REGULATION

The Traditional Environmental Regulatory Approach (TERA)

Traditionally, environmental regulation is dominated by command-and-control regulation (C&C REG), characterized by rules, hierarchy, control, deterrence, expertise and specialization. (Fiorino, 2006). "The old approach … aims to control behavior through a system of rules that prescribe uniform standards for diverse circumstances. It relies on a hierarchical model of control. Government sets requirements that regulated firms must follow. Anyone failing to meet the requirements faces penalties, in the form of fines, public censure or even criminal sanctions…this form of environmental regulation relies heavily on technical experts … also founded on specialization and division of labour" (Fiorino, 2006:6-7). Given the adversarial and deterrence character of C&C REG, there is barely any incentive for firms to reduce pollution beyond the prescribed

environmental standards set by the regulation. Firms are not encouraged to look for innovative solutions to reduce pollution beyond the prescribed limit even if they have the relevant capacity and capability because no extra economic benefits can be reaped from such additional efforts. In other words, there is no competitive advantage to be gained from TEI under the C&C regulatory model. Given that deterrence and penalty were the primary motivational strategies for meeting prescribed environmental requirements (Fiorino, 2006), C&C REG only encourages firms to carve loopholes and shirk their environmental responsibility. A long list of undesirable consequences has been attached to the old adversarial C&C REG: it impedes innovation; is inflexible, legalistic and fragmented; is expensive, irrelevant to many environmental problems and ineffective in environmental management; faces an implementation deficit, and carry the risks of business as usual (Fìorino, 2006:71-85).

Innovation Potentials of Good Environmental Regulation

In the 1990s, Porter and van der Linde argue that while adversarial C&C may discourage TEI, properly-designed environmental regulation (PD REG) can work the other way round. Porter and van der Linde (1995b) popularize the claim that properly-designed

environmental regulation may not only benefit the environment but also the regulated industries by making firms realize otherwise neglected investment opportunities, or the so called “win-win” hypothesis. Porter and van der Linde argue that strict environmental regulation and associated compliance costs could force industry to innovate and thus increase resource efficiency and enhance productivity. However, to avoid the negative consequence of poorly designed environmental regulation in the past, they note that good environmental regulations that foster TEI should be designed in such a way that create maximum opportunity for industries to innovate, should be technology-forcing instead of technology-setting, and should leave little rooms for uncertainty at every stage during the regulatory process. Specifically, they propose that properly-designed regulations should target at outcomes, not technologies; high stringency; adopt a phased approach with well-defined periods; complement with market incentives; converge with regulations in associated fields; synchronize with other countries or ahead of them; create stable and predictable regulatory process; involve industry participation from the beginning of the regulatory process and trust building; develop technical capabilities among regulators; make the regulatory process more efficient (Porter and van der Linde, 1995a, 1995b).

While it is theoretically plausible that properly-designed environmental regulation can stimulate TEI, it is debatable whether good regulations can spur environmental innovation resulting in win-win outcomes (the so called win-win hypothesis). Some qualitative case studies (e.g. Bonifant et al, 1995; Porter and van der Linde, 1995a, 1995b; Shirvastava, 1995, all cited in Bernauer et al, 2006) support the win-win hypothesis that good regulations do stimulate green innovation, whilst others remain un-supportive of such claims (Rothwell, 1992; Ogus, 1994; Jaffe, Newell and Stavins, 2004). They note the problems associated with C&C REG and its limitation in stimulating TEIs that offers high capacity for significant pollution reduction or prevention. These arguments, however, are based on the assumptions of excessive regulation, rigid, adversarial, standard-setting type of regulatory characteristics that are in use, or the complete absence of market-based instruments from the regulatory recipe. Mohr (2002) shows that there is a positive relationship between regulatory stringency and TEI. Another econometric study notes the consistency of Porter's win-win hypothesis with the economic theory. Brunnermeier and Cohen (2003) note that more stringent environmental regulation (indicated by higher abatement costs) produces only marginal influence on environmental innovation. Although more empirical results are needed to further substantiate the claim that the advocated "properly-designed" environmental regulation spurs green innovation and

achieves win-win outcomes, so far nothing seems to be against the idea that properly-designed environmental regulation creates new potentials and far better incentives for firms to seek for innovative solutions for the environment through TEIs that old adversarial environmental regulation fails to address.

EM theorists who advocate for de-centralization in policy-making and increasing dominance of market agents at the same time contend the need for traditional environmental policies to be shifting towards market-based and voluntary measures, because the traditional regulatory approach characterized by domineering, over-regulated environmental policy are taken as less effective in creating favourable conditions for environmentally-sound practices and behaviour than market-based and voluntary measures (Mol, 1995). Although this group of EM theorists makes no explicit remark of completely excluding C&C REG, increasing emphasis has been given to advocating the advantage and benefit through new environmental policy instruments (NEPIs), including market-based and voluntary instruments. Insufficient attention has been paid to eliminating the negative or adversarial effects of C&C REG on innovation and reshaping the old form of regulation into properly-designed environmental regulation that can achieve the desirable TEI and win-win EM objective.

From the firm's perspective, regulation is not as badly perceived and responded. Fiorino (2006:90) notices that the firm's response to environmental regulation is dependent upon its capability and environmental goals. More capable middle- and large-size firms are found to comply consistently or even go beyond regulatory compliance, though many of the firms, especially the smaller ones, simply want to stay below the regulator's requirements. Within the subset of progressive firms, Fiorino (2006:91) argues that reasons behind firms which resist the government's regulation is not much against the idea of government intervention and the setting-up of requirements for industries and businesses to comply with, but problems with the design and implementation of old adversarial C&C REG. Their concerns are about: the lack of flexibility or time for planning how to comply with regulations, the high transaction costs that accompany them, and the lack of clarity.

From the public policy perspective, Fiornio (2006:89) argues that over the past four decades, regulations have profoundly affected the actions of business. The regulatory stick has forced industry to pay attention to environmental damage. Through regulation,

and by combining with other non-regulatory economic and voluntary policy measures, the government will continue to influence industry behaviour. The role of government cannot be denied in terms of its legitimacy in setting collective goals and balancing the demands of competing interests in society, keeping irresponsible firms in line, and not allowing them to gain competitive advantage from their poor environmental performance.

Hence, the question is no longer about the decentralization of governance and increasing displacement from government intervention or direct environmental regulation, and the increasing replacement by NEPIs characterized by market-based or voluntary instruments, but about how to design and build a proper regulatory system that will promote the enduring greening of industry that goes beyond environmental compliance through TEI?

The New Environmental Regulatory Approach

The above therefore points to the need for the setting up of the new environmental regulatory approach (NERA) that promotes the greening of business through TEIs. The NERA targets to address the main deficiencies of the old regulatory approach and takes into account the firm's conditions. First, it is innovation-oriented so as to stimulate more

TEIs that go beyond environmental compliance and strive for win-win opportunities for both the environment and economy. Second, it targets at reducing the negative impacts of old adversarial C&C REG by improving the design and implementation of environmental regulation. Third, it targets to address the specific factors/conditions that affect TEIs at the firm-level, that is, creating favourable conditions that maximize incentives, strengthening innovation capabilities and attending to the stakeholder's perception about technological change, as well as to reducing market and non-market barriers that impede firms from engaging in TEIs.

To achieve this end, it is proposed that the NERA has the following characteristics:

First, to improve the innovative potential of environmental regulation, we propose an innovation-oriented approach to environmental regulation which departs from the traditional standard-setting approach. By innovation-oriented, we mean the setting up of goal-oriented, innovation-driven regulatory approach for steering TEIs. This would not have been possible without creating in environmental regulation *stringency* and *flexibility*. Stringency provides the necessary stick or the regulatory pressure for firms to set higher environmental objectives and invest in TEIs that provide a better potential for achieving

higher environmental performances and meeting the more stringent targets (Porter and van der Linde, 1995a, 1995b; Fiorino, 2006: 200; Ashford, 2000, 2002). On the other hand, environmental compliance should allow flexibility as to provide more space for firms to select the most cost-effective environmental technologies based on their own capabilities (Porter and van der Linde, 1995a, 1995b). In this regard, it is argued that technology-forcing instead of technology-setting regulations are preferred, as the former provides more flexibility for firms to meeting the environmental objectives without risking themselves from picking up the cost-ineffective environmental technologies (Jaffe, Newell and Stavins, 2004).

To minimize the negative consequences of adversarial, C&C REG, and maximize the potentials of environmental regulations, it is proposed that the following regulatory characteristics should be taken into account when designing and implementing environmental regulations with the aim to steer TEIs (Porter and van der Linde, 1995a, 1995b; Kemp, 1997; Klemmer, Lehr and Lobbe, 1999; Ashford, 2000, 2002):

1. Goal-setting: environmental regulation should focus on long-term, broad, systemic goals, in order to steer regulated firms to seek for most innovative solution, instead of

forcing them to adopt particular technologies (technology-setting) or complying with environmental standards (standard-setting).

2. Stringency: environmental regulation should provide impetus for regulated firms to strive for higher environmental performance.

3. Flexibility: environmental regulation should increase the flexibility for regulated firms in terms of how they are to achieve the regulatory target.

4. Certainty: environmental regulation can be designed in such a way that reduces the uncertainty in what the regulated firms are to accomplish. This will help firms to plan ahead of time and look for innovative solutions to meet the regulatory target. This can be implemented by means of phase-in periods and well-defined targets, and enhanced through early announcements.

5. Consistency: environmental regulation should standardize one environmental regulation with other regulations in associated fields. For instance, the introduction of stringent fuel standards can eventually stimulate search for new environmentally friendly energy and vehicle technologies that produces lower vehicular emissions.

6. Incentive-driven: environmental regulation can be designed in such a way that maximizes and continuously creates incentives for innovation and encourages the

creative use of technologies that exceeds current regulatory standards by coupling environmental regulations with other incentive-based instruments. This can be done by complementing regulatory instruments with pollution charges, tradeable permits, or credit system that provide market incentives for industries to continuously improve environmentally through TEIs.

7. Participatory: environmental regulation should encourage industrial participation in the design of phase in periods, the content of regulations and regulatory process, trust-building, and self-regulatory behaviours, such as information disclosure.

8. Capability-enhanced: environmental regulation should enhance managerial competence and thereby receptivity, by introducing voluntary programmes in the form of technical assistance, demonstration projects, education and training programmes and appropriate technological consulting services.

Finally, by changing the design and implementation of environmental regulation to include the above regulatory characteristics, the NERA targets to create economic incentives, enhance innovation capabilities, and change perceptions that create the favourable conditions that are necessary for firms to conduct TEIs.

For instance, a highly stringent Zero Emission Vehicle (ZEV) Program has been established since 1990 by the California Air Resources Board in an attempt to regulate the worsening air quality in California. Under the ZEV Regulation, it requires a certain percentage of the vehicles produced for sale in California be zero-emission. The latest 2008 option requires the range of ZEVs or Partial ZEVs to be produced in 2012-14 and 2016-17 to be 7,500 ZEVs plus 58,000 PZEVs, and 25,000 (ZEV) respectively (CARB, 2008). Despite several failures and setbacks for the industries to meet its regulatory requirements, it is undeniable that ZEV Regulation has pushed the relevant industries to search for advanced cleaner automobile technologies such as fuel cell or other advance vehicle technologies that carry extremely low or zero emission levels. By 1998-2003, the major manufacturers placed over 4,000 battery-powered ZEVs in California. The ZEV Regulation also spurred advances in natural gas and other alternative fuelled vehicles, super-clean gasoline vehicles, fuel-efficient hybrids, and fuel cell vehicles powered by electricity created from pollution-free hydrogen (CARB, 2004). The ZEV program has been designed with an aim to provide continuous incentives for out-performance. While demanding goals are necessary to exert pressure on the industries and thus provide negative incentives to go beyond existing environmental performance, regulation should

equally be designed to create positive incentives that awards industries that are able to take up innovative approaches and achieve better results. These can be done in the form of market incentives such as emission trading, certification schemes or credit programmes that creates monetized or non-monetized incentives for industries to continuously innovate and outperform their counterparts. For instance, a credit system has been introduced under the Zero Emission Bus (ZEBus) Regulation to encourage bus transit companies to go beyond the environmental targets set in the ZEBus Regulation. In this regard, the use of market-based and voluntary instruments may help achieve the desirable results.

It must also be understood that without the relevant capabilities that support technological innovation, firms cannot embrace TEIs. Organizational, technological and technical capabilities should be ready in order to bring about a technological transition. As such, there is a need for regulation to be capability-enhanced, that is, the regulation should create opportunities for firms to build up their innovation capabilities over time. Asford (2000, 2002) suggests that it is important to address managerial competence and ultimately improve the managerial receptivity towards technology change, by means of voluntary instruments such as technical assistance, demonstration projects, continuing

education of engineers, and the provision of appropriate technological consulting services. Fiorino (2006:203-4) argues that a firm's capacity in environmental performance is linked to its capacity in learning. Regulations should increase its flexibility and reduce its complexity and rigidity which will enable both the industry to change their behaviour in response to what they learn.

To change managerial perception and mobilize industries to take up more innovative approaches for better environmental performance, a participatory approach is preferred. Regulation can be designed in a way that encourages trust-building and dialogue between the regulated firms and the regulators, and encourages self-regulatory behaviours. Fiorino (2006:206) argues that distrust always increases transaction costs and encourages low-risk response to regulatory standards, and shifts attention and resources from performance to narrower issues of compliance. To encourage industries to innovate, it is very important for new environmental regulations to motivate regulated parties to deliver their commitments. This can be done by means of complementing environmental regulations with voluntary challenge programmes so that those regulated firms with a good history of self-compliance and those outperformed ones are given the chance and trust to design their own approach and deadline of delivering their self-regulatory

environmental commitments. Other voluntary programmes such as partnership, technology demonstration or training programmes carry the potentials for trust-building, improving dialogue and gathering managerial, organizational and societal receptivity for technology change (Norberg-Bohm and de Bruijn, 2005).

Further, by designing environmental regulation with a higher flexibility, stringency, certainty, consistency, it removes the non-market barriers such as uncertainty, negative externality, spillover and information asymmetry that hinder TEIs. For instance, the introduction of well defined phase-in periods under the ZEV Regulation removes the uncertainty and allows industries to plan ahead to search for innovative solutions instead of going hastily to patch problems. Properly-designed environmental regulation also carries the potential to reduce market barriers such as spillover. For instance, by designing environmental regulation and well defined phase in periods, it provides a level playing field for all companies such that no one can opportunistically gain position by avoiding environmental investment. Laggards will not be entitled to further economic/non-economic benefits as previously gained from knowledge spillover; leaders are incentivized to innovate and stay ahead of others. Further, environmental regulation can be set in a way that requires regular company environmental reporting and mandatory

information disclosure in order to improve information transparency and reduce market barriers to TEIs due to information asymmetry.

In conclusion, the main package of NERA includes:

1. The establishment of innovation-oriented environmental regulation, in replacement of old adversarial command-and-control environmental regulation.

2. Change in the design and the implementation of new form of environmental regulation that incorporates into it the characteristics of goal-setting, stringency, flexibility, certainty, consistency, incentive-driven, participatory and capability-building.

3. Complementation of regulatory with incentive-based and voluntary components to create favourable conditions for firms to conduct TEIs.

CASE STUDY: ZERO EMISSION BUS REGULATION IN CALIFORNIA

In the following, we will investigate how the California Zero Emission Bus Regulation (ZBus), which resembles NERA, creates favourable conditions for TEI than the TERA

approach as proposed by some EM theorists. Amid a series of efforts to combat air pollution in California, the Air Resources Board (CARB) established a new bus fleet regulation in 2000 with the target to reduce emissions from transit buses in California. The ZBus Regulation is part of the Fleet Rule for Transit Agencies, which is also referred to as the Public Transit Agencies Regulation. The ZBus Regulation is designed to encourage the operation and use of zero emission buses in urban bus fleets first through demonstration projects followed by ZBus purchasing and leasing requirements. Same as the ZEV Regulation, the ZBus Regulation is highly stringent which requires a certain percentage of purchase and lease agreements of urban buses be zero-emission buses. The current amendment requires transit agencies on the diesel path to have at least minimum of 15% purchase and lease agreements be zero-emission buses by 2011 – 2026 whenever zero-emission buses become available in the market (CARB, 2009a).

Since the ruling in 2000, several transit agencies have started developing demonstration programmes on zero-emission fuel cell buses (US Department of Energy, 2006). Starting from 2005, three service providers, including SunLine Transit, AC Transit and Santa Clara VTA have started experimenting and demonstrating fuel cell fleets in Santa Clara, Oakland and Palm Springs within the California. As of 2009, a total of seven

zero-emission buses have been running on the streets in California under California Fuel Cell Partnership (CaFCP), which creates collaborative opportunities between automobile manufacturers, fuel cell suppliers, and local transit agencies for pushing forward zero-emission vehicles (CARB, 2009b). Both AC Transit and SunLine Transit are the early adopters of advanced clean technologies including Compressed Natural Gas (CNG) and hydrogen CNG prototypes as well as fuel cell buses. SunLine Transit is also an early adopter of hydrogen fueling facilities in 2000 (see Table 1, US Department of Energy, 2003a).

Bus Co.	Operation Area	Vehicles	Rider-ship	No. of Fuel Cell Vehicles	Fuel Cell Supplier	Demon-stration	Started Since	Clean Fuels/Vehicles Initiatives
SunLine Transit	1100 sq miles; covering 9 member cities as well as Riverside County	48 buses; 24 vans		1 fuel cell bus; 1 hydrogen hybrid ICE	AC Transit (subcontracted from ISE Research and UTC Fuel Cells)	2000	Dec 2005	Introduced aggressive strategy to implement clean technologies into its fleet by switching its fleet progressively switching to CNG then to more advanced technologies Hydrogen CNG blended fuels and fuel cells; Opened a hydrogen production facility for demonstration starting from 2000
AC Transit	360 sq miles, service to East Bay of San Francisco	638	65 M/yr	3 fuel cell buses	ISE Research and UTC Fuel Cells	Late 1999	Mar 2006	Opportunity to test early prototype fuel cell buses
Santa Clara VTA	326 sq miles; provide service in and around Santa Clara VTAArea and other areas	423	39 M/yr	3 fuel cell buses (low floor fuel cell buses)	Gillig Corporation and Ballard Power Systems	Aug 2004	Feb 2005	Partnering with San Mateo County Transit District (SamTrans) for fuel cell demonstration

Table 1. Operational Characteristics of Fuel Cell Bus Demonstration Transit Agencies in California

The ZBus Regulation

The ZBus Regulation (CARB 2009a) contains the following components:

1. A clear definition on what can be classified as a ZBus.
2. A section outlining details on the requirements and specifications for conducting ZBus demonstration for the Initial Demonstration Project:
    a. What type of transit agencies are required to conduct ZBus demonstration
    b. What requirements and deliverables the transit agencies are to attain, including the minimum ZBus to be demonstrated onto the streets, requirements for availability relevant supporting infrastructures, maintenance and storing facilities, training of personnels, duration of demonstration, together with operational and maintenance information keeping and reporting
    c. Well-defined periods for meeting each specific requirements or specifications
    d. Conditions and requirements for joint demonstration among multiple transit agencies.
3. A section outlining details on the requirements and specifications for conducting ZBus demonstration for the Advanced Demonstration Project. Details are much the same except that the number of ZBus required for demonstration is double of that required within the Initial Demonstration Project, and that path transit agencies are given the flexibility to follow the single or joint path demonstration, and that the conditions and requirements for joint demonstration among multiple transit agencies differ from those established for the Initial Demonstration Project.

Credits to be provided for the demonstration of ZBuses can also be identified in this section.

4. A section outlining details on purchasing requirement for ZBus. The main difference of this section from Section (2) or Section (3) is that there is a requirement for a certain percentage of purchase and lease agreements to be achieved within a specified duration. Grace period is given before the implementation of the regulatory requirements. Further, a system to award transit agencies which engage in advanced purchase of ZBus in order to encourage early adoption of ZBuses is in place. Purchase credits are also accrued for advanced demonstration of ZBus. This means earlier the demonstration and purchase of ZBuses, the higher the credits and purchase credits earned for affected transit agencies. Conditions for the eligibility of accruing credits are specified. The Regulation also provides provisions for reviewing ZBus technology and the feasibility of implementing requirements of the credit system before a certain deadline.

ZBus Regulation and NERA

A brief overview reveals that ZBus Regulation possesses some of the regulatory characteristics of NERA (see Table 2). To a certain extent, ZBus Regulaton is goal-driven. Its focus is to encourage the operation and use of clean ZBus technologies in urban bus fleets in California, instead of forcing the transit agencies to align with particular technologies. The goal is highly stringent too. By setting the target at zero emission, it creates a strong regulatory stick (or negative incentive) to push forward transit agencies

to collaborate with automobile suppliers in search of alternative fuel technologies that can meet the stringent requirements. This is further enhanced through well-defined deadlines of regulatory compliance, which removes the uncertainty for technological investment and creates a level-playing field for companies to compete with each other through TEIs. Credit award systems are established under ZBus Regulation to provide an impetus for continuous innovation because transit agencies which undertake ZBus demonstrations or purchase of ZBuses in advance are given credits or purchase credits. The earlier the demonstrations/purchase of ZBuses, the higher the credits accrued. This provides a positive incentive and an impetus for transit agencies to develop advanced cleaner technologies early in exchange for more credits. The design of ZBus Regulation with well defined phase-in period also ensures that companies are given the time flexibility in search of innovative solutions instead of falling into a scenario to implement expensive solutions hastily to patch problems. Further time flexibility is given in the form of grace period assigned for demonstration. This provides the time that allows transit agencies to develop their relevant innovation capabilities in transiting towards the advanced vehicle technologies. Options for joint implementation enhance inter-organizational learning and resource sharing with the possibility to further strengthen innovation capabilities of individual transit agencies. The establishment of CaFCP also boosts the innovation competence of transit agencies through partnerships and collaborations with a wide array of stakeholders possessing different capabilities and resources. The requirement for demonstration under the ZBus Regulation allows the building up of innovation competence and provides the transit familiarize with a testing ground to test their capabilities in adapting to new environmental technologies, as well as firm receptivity towards previously unfamiliar environmental technologies such as fuel cell buses.

Furthermore, participation is allowed under the ZBus Regulaton, in the form of regular meeting with industrial stakeholders and public consultation. These open up the opportunities for dialogue and communication, as well as opportunities for relationship and trust building between the regulated and the regulators. It results in an improvement in the receptivity of agencies towards the ZBus regulatory requirements and active search of TEIs instead of negatively resisting the regulatory requirements.

NERA Regulatory Characteristics	Evidence
Goal-setting	The goal of encouraging the use and operation of zero-emission buses (ZBuses) in California is established by CARB.
Stringency	High stringency. ZBus Regulation requires that a certain percentage of buses purchased or leased should be ZBuses before commercial ZBuses are available. The Regulation requires transit buses to commit in the demonstration of a certain number of ZBuses on street.
Certainty	Deadlines for ZBus demonstration and well defined phase-in periods for demonstration of certain percentage of ZBuses are established. Also it provides clear deadlines for compliance with other specifications and requirements, such as bid proposals for materials and services in support of demonstration project, initial and final reporting.
Consistency	It is broadly consistent with another fleet rule established by CARB, the ZEV Mandate or ZEV Regulation.
Flexibility	Transit agencies are given a grace period to implement ZBus demonstration programmes and options for joint implementation of demonstration and purchase/leasing agreements of ZBuses are provided.

Incentive-driven	Credit award systems are provided to encourage early adoption of advanced ZBus technologies. The earlier the adoption, the higher the credits accrued. This triggers off an incentive for search for innovative solutions for transit agencies to achieve earlier compliance in exchange for credit awards (which can be in the form of purchase credit, for instance, 1 purchase credit = 1 ZBus)
Participatory	The government has extensive consultation with the transit agencies and other stakeholders, through regular meetings with the regulated parties and consultations with the public.
Capability-enhanced	The option for joint participation between transit agencies creates opportunities for inter-organizational learning and sharing of funding resources. The availability of CaFCP in addition provides opportunities for transit agencies to team up auto manufacturers, energy companies, fuel cell technology companies and government agencies at the local, state and federal levels in fuel cell demonstration. The requirements for proposal submission and reporting facilitate institutional learning and prepare firms for new and unfamiliar technologies.

Table 2. Regulatory Characteristics of ZBus Regulation

Favourable Innovation Conditions: What is the Role of ZBus Regulation?

In the following, citing from the case of ZBus Regulation introduced in California by California Air Resources Board, we demonstrate how the New Environmental Regulatory Approach enhances the favourable innovation conditions that are needed for transit agencies to engage in ZBus demonstrations.

In the previous session, it has been argued that three favourable innovation conditions, namely, economic incentives, innovation capabilities and stakeholder norms, attitudes and behaviours, are known to influence firm-level TEI decisions and behaviours. For firm-level TEIs to occur, environmental regulations and policies should target at creating economic incentives, enhancing innovation capabilities, and changing stakeholder perceptions and receptivity towards technology change.

First of all, it is noticed that the demonstration and purchase of unconventional zero emission buses such as the fuel-cell prototype requires substantial financial investment in the short term, with profit-returns not obtainable in the foreseeable future. It is estimated that the current technology costs for a fuel cell electric technology is US$2,200,000 (CARB, 2009c), this is about double of the cost of CNG Hybrid Electric or Battery Electric, or almost four times the cost of Diesel Hybrid Electric. The current technology cost scenario makes the demonstration or purchase of zero-emission fuel cell buses a financially unattractive option. Hence, without a strong regulatory pressure, it is very difficult to create a strong negative incentive for transit agencies to pursue the

zero-emission technology and collaborate with the automobile suppliers and fuel cell technology developers. The guiding principle of ZBus Regulation includes the objectives of meeting California's criteria pollutant and GHG emission reduction goals, helping the development and commercialization of zero-emission technologies, and ensuring the transit agencies to be able to cost effectively replace a diesel or CNG bus with a zero-emission bus (CARB, 2009c). With clearly defined goals, and highly stringent regulations, ZBus Regulation sends forth a clear message and sets forth a strong impetus to mobilize transit companies to start searching for advanced cleaner environmental technologies that can meet the stringent requirements.

Unlike the TERA, the ZBus Regulation is designed to reduce the rigidity by making it technology-forcing instead of technology-setting. In addition to the fuel cell technologies, other technologies such as electric cars are potentially possible to attain the zero emission target. ZBus Regulation is also designed with clearly defined time frames for regulatory compliance. The early announcement of the regulation provides a consistent and definite signal so that industries can plan ahead and search for more cost-effective solutions instead of being forced to hastily comply and locked into expensive options. The regulatory imperative alerts the California transit agencies to the need of continuously upgrading their technological, technical and organizational capabilities to meet the zero-emission requirements. It also removes the rigidity of NERA with increasingly

flexibility in terms of what technological options one can choose and when one is to comply. The stringent emission requirements and implementation schedule sets an imperative for the California transit operators to conduct ZBus demonstrations. An evaluation report (CARB, 2006) on ZBus Regulation showed that ZBus has successfully kick-started transit agencies' pursuit of fuel cell transport technologies.

"Based on demonstrated performance, expected cost and availability, transit agencies viewed the fuel cell engine as the transportation industry's environmental solution and eagerly initiated efforts to further test and evaluate fuel cell buses. In addition, at the time the transit bus regulation was developed, information available to staff indicated that the research and development of fuel cells would result in their market application in transit buses before their application in light duty vehicles (CARB, 2006)."

Regulatory pressure alone, however, would not enable the service providers to successfully engage in ZBus demonstration or purchase. For transit agencies to purchase technologically unproven and commercially immature technologies involves high investment capital and high economic risk. Economic incentives must be sufficiently provided to counter-balance the cost sheet. ZBus Regulation is established with the goal to encourage development and commercialization of ZBus technology (CARB, 2009c). A number of supporting policies have been in place in support of ZBus. First, three major transit agencies' fuel cell demonstration programmes were supported by both public and

private funding, in which the government is the major funding source (CaFCP, 2007a). Eighty percent of the purchases of transit buses and supporting infrastructure are funded by the local, state and federal government agencies and the rest twenty-percent is obtained from other funding sources (US Department of Energy, 2007). Furthermore, a credit system is in place to encourage advanced demonstration and purchase of ZBus options, the earlier the adoption, the higher the credits/purchase credits gained. This provides additional incentives for transit agencies to overcome the cost-benefit imbalance and makes the demonstration or purchase of ZBus options more viable. It is estimated that the total cost of purchasing fuel cell buses for all transit agencies will range from US$32 million starting in 2012 to US$59 million starting in 2015. The award credit system and the initial private and public financial aids also helped the providers positively to overcome part of the entry barriers.

Economic incentives alone, as argued in previous sections, does not account for all factors that determine firm-level TEIs. Innovation capabilities, in the form of technical, technological and organizational capabilities must be addressed. In order to transit from existing diesel pathway to new technological pathway, it requires transit agencies to establish infrastructural, operational and maintenance systems for new sets of technological and operational skills and expertise. Along with supportive policy programmes such as the CaFCP, ZBus Regulation enhanced the innovation capabilities of transit agencies by requiring ZBus demonstration. The setting up of phase-in periods and ZBus demonstration and constant reporting to the regulators helps transit equip themselves with the necessary capabilities towards the zero-emission pathway. ZBus demonstration helped them familiarize with ZBus development, operation and

maintenance. The option that allows joint implementation is also a clear indication that ZBus Regulation has taken into account of the constraints in terms of resources and expertise that transit agencies might face in regulation compliance. The setting up of CaFCP provides a platform to team up transit companies, auto manufacturers, energy companies, fuel cell technology companies and government agencies to push forward fuel cell commercialization. Since its establishment in 1999 by two California state government agencies in joint efforts with six private companies, it has continued to play a pivotal role in providing the essential infrastructural, technological and institutional support (CaFCP, 2007b). The information collected by the regulators in return can help the regulators evaluate the feasibility of ZBus technologies and modify regulatory requirements.

Stakeholder norms, attitudes and behaviours impact significantly firm decision-making on technology change. The ZBus regulation has been characterized by a participatory process that kickstart dialogues and communications between public stakeholders and the regulators. Regular public workshops were held to review the ZBus regulation. Information and ideas on ZBus regulation were collected from public stakeholders. Trust between the government and the transit operators and the public community at large was built up. Award schemes under ZBus Regulation reinforce the government's determination to encourage zero-emission bus demonstration and purchase instead of penalizing them for non-conmpliance (CARB, 2009b). The collection of public opinions and constant dialogues with public stakeholders also fosters a trust-building relationship and steers stakeholders to shift towards the zero-emission pathway.

CONCLUSION

Against the background of ecological modernization which takes on the assumption that a more positive relationship between the environment and economy is achievable through TEI, this paper examines what factors influence the adoption of TEIs and highlights what role environmental regulation can play in stimulating TEIs and achieve the win-win environmental-economic objective. The New Environmental Regulatory Approach (NERA) is proposed, it departs from Traditional Environmental Regulatory Approach (TERA) in terms of its innovation orientation. It features the following design and implementation characteristics: goal-setting, stringency, flexibility, certainty, consistency, incentive-driven, capability-enhanced. It aims to enhance the economic incentives, innovation capabilities and the stakeholder norms, attitudes and behaviours which offer potential for continuous environmental improvement and economic competitiveness.

On the one hand, the paper argues against the TERA which has repeatedly been considered to be ineffective in mobilizing companies to continuously improve their environmental performance due to its adversarial, inflexible and command and control regulatory nature. On the other hand, there is a reservation to increasingly shift towards NEPIs, as stringent environmental regulation is a necessary component to provide a huge negative incentive to trigger continuous environmental improvement through TEIs. Our argument is therefore to capitalize on the strengths of good environmental regulation, and strengthen its capacity to create the favourable conditions, including market incentives, innovation capabilities and stakeholder receptivity towards technology change by complementing it with incentive-based and voluntary measures.

Using the case of Zero Emission Bus Regulation introduced by California Air Resources Board adopted in 2000, we argue that this type of regulation resembles NERA and sharing similar regulatory characteristics in terms of its innovation orientation, goal-setting, high stringency, certainty, consistency, incentive-driven, participatory and capacity-building. The Regulation creates a high regulatory stick, i.e. zero-emission target, and is complemented with other supportive policy packages, such as financial support, credit system, and voluntary programmes which support collaborative efforts in searching for zero-emission technologies that can meet the stringent zero-emission requirement. The programme mobilized transit agencies in California to commit to fuel cell bus and other ZBus demonstrations. Considerable success has been achieved in the initial demonstration of ZBuses. A total of seven ZBuses, six of them of the fuel cell prototype, have been put onto streets in California for demonstration. Five Bay Area transit agencies will participate in twelve advanced bus demonstrations this year. The regulatory requirement for 15% of the buses purchased to be ZBuses by 2011 or 2012 will provide a significant imperative and continuous impetus to mobilize transit agencies to commit to fuel cell demonstration projects, and the development and commercialization of ZBuses in California. ZBus Regulation offers an example of how properly-designed and implemented environmental regulation are able to create favourable innovation conditions that change the relationship between environment and economy to a more positive end.

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