Ecological Modernization and Environmental Innovation:

What is the Role of Environmental Regulation?

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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 or 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 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 overcoming of barriers such as uncertainty, negative externality, spillover problem and 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 such a measure is profitable in the long run.

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 C&C 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: 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. 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 perception 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 facilitate 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 as a critical means to achieve both economic gain and environmental performance at the same time in the Ecological Modernization Theory (EMT). The adoption of TEI can not only reduce emissions and the consumption of resources but also improve the eco-efficiency to bring about better competitiveness (Gouldson and Murphy, 1998). 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 conduct 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 Traditional Environmental Regulatory Approach (TERA) are taken as less effective in creating favourable conditions for environmentally sound practices and behaviour than market-based and voluntary measures, because of its adversarial, inflexible, and command-and-control regulatory characteristics (Fiorino, 2006). 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.

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 discouraging companies from searching for innovative solutions and achieving outstanding environmental performance. NERA advocates for the replacement of traditional C&C environmental regulations with new environmental regulations that are innovation-oriented, and are properly-designed and implemented with the incorporation of new regulatory characteristics: goal-setting, stringency, flexibility, certainty, consistency, innovation-oriented, participatory, capability-enhanced, in order to create favourable innovation conditions for firm-level TEIs. NERA implies the need for the regulatory component to couple with the market-based and the voluntary component that offer additional incentives, facilitate innovation capabilities, and steer managerial perception and receptivity towards technology change. On the one hand, the regulatory component of NERA guarantees that firms are motivated to continuously search for new TEIs to meet the constantly tightening standards. On the other hand, the incentive and the voluntary component facilitate 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 (ZEBus) 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 of 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 through 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 whenever the associated economic benefit overrides cost, and that market failures and barriers, such as negative externality, information asymmetry and 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 on whether to pursue a TEI is economic incentive. From the neoclassical perspective, profit maximizing firms will undertake TEI only if the economic benefits of innovation override the costs. The incentivizing factors include direct and indirect economic benefits, as well as non-economic benefits translatable in economic terms. Direct economic benefits in the form of cost-effectiveness and profitability serve the most direct and essential incentive for profit-maximizing firms to kick-start a TEI. 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 gained through product differentiation. These indirect incentives provide the necessary impetus for firms to engage in TEIs where immediate innovation offsets are not readily available. Other non-economic benefits that often associate 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 direct or indirect economic benefits and the lower the costs that are involved in TEI, the bigger the economic incentives for conducting 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 goods and services provided by the environment for free. Firms are better off by not conducting TEI as any effort of doing so creates only costs other than additional benefits. Few incentives can be expected from TEI for companies if negative externality is not being internalized. Positive externality, in the form of knowledge and adoption externalities, encourages less than the expected level of TEI because of spillover effect. Given that late innovators or adopters can always benefit from knowledge or adoption spillover of the first-movers, in the form of dynamic increasing returns, it is economically non-beneficial for first-movers if mechanisms to safeguard against knowledge or adoption spillover are absent. Incomplete information prevents rational decision-making of technology choices, creating uncertainties concerning environmental investments and triggers off underinvestment of TEI in some instances. 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 will become more exemplified if the shift involves broader social interests. Social resistance to existing technologies introduces further uncertainty about profit returns 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) considers these the essential capabilities for a firm to integrate new knowledge into its 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 that enable organizational and technological restructuring to take place within 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 require 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 TEI. 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 risks in association with the proposed TEI, the lower the willingness to adopt (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 is taken as deeply embedded within its social and political context (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 the potentially higher societal acceptability and lower resistance that associate with the technology choice.

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 behaviour 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 the additional efforts. There is no competitive advantage to be gained from TEI under the C&C regulatory model. Instead of meeting prescribed environmental requirements, C&C REG encourages firms to carve loopholes and shirk their environmental responsibility (Fiorino, 2006). The long list of undesirable consequences attached to the old adversarial C&C REG include: innovation-retarded; inflexible, legalistic, fragmented, expensive, irrelevance to environmental problem-solving, ineffectiveness in environmental management; implementation deficit, as well as risks of business-as-usual (Fìorino, 2006:71-85).

Innovation Potentials of Properly Designed Environmental Regulation

In the 1990s, Porter and van der Linde argue that while adversarial C&C REG 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 PD REG 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. Their argument is rested upon the assumption 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 regulations, they note that good environmental regulations that foster TEI should be designed in such ways that create maximum opportunity for industries to innovate, are technology-forcing instead of technology-setting, and leave little rooms for uncertainty at every stage of the regulatory process. Specifically, they propose that properly-designed regulations should target at outcomes instead of technologies, aim at 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 PD REG can stimulate TEI, it is debatable whether this is practicably achievable especially when both environmental and economic competitiveness are targetted (so-called Porter's 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 can stimulate green innovation, whilst others remain skeptical 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 inducing TEIs that offers high capacity for substantial pollution reduction or prevention. Their arguments, however, are based on the assumptions of excessive regulation, as well as rigid, adversarial, standard-setting type of regulatory characteristics that are in use, or the complete absence of market-based instruments in 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) observe that more stringent environmental regulation (indicated by higher abatement costs) produces only marginal influence on TEI. 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 no conclusive remarks is against the idea that PD REG creates a greater potential and a much more powerful incentive for firms to pursue green technological solutions in comparison with conventional C&C REG.

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 shift towards market-based and voluntary measures, because the conventional domineering, over-regulated environmental policies are taken as less effective in creating favourable conditions for environmentally-sound practices and behaviour than market-based and voluntary measures (Mol, 1995). For EM theorists who contend for the decentralization of governance and the increasing dominance of market agents, increasing emphasis is placed on the benefits that new environmental policy instruments (NEPIs) including market-based and voluntary instruments, can bring about in steering change in conditions in favour of TEI. Insufficient attention has been paid to eliminating the negative or adversarial effects of C&C REG on innovation and reshaping them to PD REG that offers a much promising potential for realizing the win-win EM objective.

Observing from a firm-level perspective, regulation is not as badly perceived and responded among firms with better capabilities and clearer environmental goals. Fiorino (2006:90) notices that 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) contends that a firm's resistance to government's regulation is not much about government intervention and the rules of compliance, but more about problems concerning the design and implementation of old adversarial C&C REG. Their major blockades of complying with current environmental regulations involve: the lack of flexibility or time for planning how to comply with regulations, the associated high transaction costs, and the lack of clarity.

Viewing from a public policy perspective, Fiornio (2006:89) argues that over the past four decades, environmental regulations have profoundly affected business responses towards the environment. The regulatory stick has forced industry to pay attention to environmental damage. It is predicted that a positive change in firm's environmental behaviour can be found with the introduction of mandatory regulation alongside with non-regulatory economic and voluntary policy measures. It is also concluded that the government plays a crucial role in such process, by setting collective goals and balancing the demands of competing interests in society, keeping irresponsible firms in line, and not allowing low-environmental performance firms from gaining competitive advantage.

The New Environmental Regulatory Approach

The above discussion therefore points to the superiority of the new environmental regulatory approach (NERA) in changing a firm's environmental behaviour and steering TEIs to TERA. NERA targets to set apart from the compliance-oriented TERA and to attend specifically to the firm's innovation conditions. First, it is carried with an innovation orientation with a target to encourage firms to go beyond environmental compliance and strive for superior environmental performance by conducting TEIs. Second, it targets at reducing the negative impacts of adversarial C&C REG by improving the design and implementation of environmental regulation. Third, it targets to attend to the specific innovation conditions, by maximizing incentives, strengthening innovation capabilities, changing stakeholder's perception towards technological change, and reducing market and non-market barriers that impede firms from engaging in TEIs, thereby creating favourable conditions for TEIs.

To improve the innovative potential of environmental regulation, we propose the adoption of an innovation-oriented approach to environmental regulation. By innovation orientation, we refer to goal-oriented, innovation-driven environmental regulations. A case in point is the ZEV program introduced by California Air Resources Board in California, which is designed with an aim to provide continuous incentives for out-performance in car environmental technologies (CARB, 2004). Regulatory *stringency* and *flexibility* are considered necessary characteristics to attaining the regulatory goal. Regulatory stringency provides the regulatory stick to pressurize firms to adopt TEIs and attain the higher environmental targets (Porter and van der Linde, 1995a, 1995b; Fiorino, 2006: 200; Ashford, 2000, 2002). For example, the highly stringent Zero Emission Vehicle (ZEV) Program established since 1990 by the California Air Resources Board has pushed the relevant industries to pursue advanced car technologies that produce low or zero emissions. The ZEV Regulation requires a certain percentage of vehicles 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). By 1998-2003, the major manufacturers placed over 4,000 battery-powered ZEVs in California (CARB, 2004). Regulatory flexibility provides the space for firms to pick up the cost-effective environmental technologies based on individual capabilities (Porter and van der Linde, 1995a, 1995b). As such, environmental regulations based on technology-forcing standards is preferred to technology-setting standards, as the former provides more flexibility for firms to attain environmental objectives without the need to resort to cost-ineffective technological options for environmental compliance (Jaffe, Newell and Stavins, 2004).

To minimize the negative consequences of adversarial, C&C REG, and to maximize the potentials that environmental regulations can achieve in terms of inducing firm-level adoption of TEIs, the following characteristics are to be incorporated at the stage of regulatory design and implementation (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, as to steer regulated firms to seek for the most innovative solution (technology-forcing), instead of mandating particular environmental technologies (technology-setting) or particular environmental standards (standard-setting).

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

3. Flexibility: environmental regulation should increase the flexibility to allow firms to freely decide their own ways of meeting the regulatory target.

4. Certainty: environmental regulation can be designed in such a way that reduces the uncertainty in when and what the regulated firms are to accomplish. Regulatory certainty can be achieved by means of introducing phase-in periods, well-defined environmental targets, and coupled with early announcements. The higher the regulatory certainty, the more predictable the negative consequence of non-compliance, and the greater the motivation for firms to plan ahead and commit in better environmental performance.

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 the search for new environmentally friendly energy and vehicle technologies that generate 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 systems that create market momentum and incentives for continuous environmental improvements through TEIs.

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

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

To specifically attend to innovation conditions governing TEIs, NERA can be designed and implemented in ways that maximize economic incentives, enhance innovation capabilities, and change managerial and societal perceptions in support of TEIs.

Whether a firm will engage in TEIs is dependent upon financial returns. Environmental regulation that alters the cost-benefit calculus by inducing economic incentives and shifting the calculus towards the positive end is fundamental to motivate firms to innovate. In most cases, environmental regulation can integrate with market-based/ economic instruments, such as taxes/charges, emission trading, or voluntary programmes, such as certification schemes or credit programmes to provide the economic incentives for industries to offset the cost of TEIs. For instance, a credit system was introduced under the Zero Emission Bus (ZEBus) Regulation to encourage bus transit companies that go beyond the environmental targets set in the ZEBus Regulation. Early adopters of ZEbuses are given extra credits or quotas of exemption from purchasing ZEBuses.

It must also be understood that without the relevant capabilities that support technological innovation, firms will not be able to engage in TEIs. Organizational, technological and technical capabilities should be possessed by firms before a technological transition can occur. As such, there is a need for environmental regulation to be capability-enhanced, that is, the regulation should create windows of opportunities for firms to establish 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, technology demonstration, 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. To kickstart technological transition, environmental regulations should increase its flexibility and reduce its complexity and rigidity and complement with voluntary instruments so as to mobilize managerial and organizational learning, as well as to enhance the organizational capacity in support of technological transitions.

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 challenging programmes so that regulated firms with a good record of self-compliance and the outperformed ones are given the chance and trust to design their own approach of delivering their self-regulatory commitments. Other voluntary programmes such as partnership, technology demonstration or training programmes also offer 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 and 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. 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 introduction of innovation-oriented environmental regulation, in replacement of old adversarial command-and-control environmental regulation.

2. Change in the design and the implementation 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 investigate how the California Zero Emission Bus Regulation (ZEBus), which resembles NERA, creates more favourable conditions for TEI than TERA. 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 ZEBus Regulation is part of the Fleet Rule for Transit Agencies, which is also referred to as the Public Transit Agencies Regulation. The ZEBus Regulation is designed to encourage the operation and use of zero emission buses in urban bus fleets first through demonstration projects, followed by ZEBus purchasing and leasing requirements. Same as the ZEV Regulation, the ZEBus 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 in California. As of 2009, a total of seven zero-emission buses have been running on the streets 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 ZEBus Regulation

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

1. A clear definition on what can be classified as a ZEBus.
2. A section on the requirements and specifications for conducting ZEBus demonstration for the Initial Demonstration Project:
   a. The kinds of transit agencies that are required to conduct ZEBus demonstration
   b. The requirements and deliverables that the transit agencies are to attain, including the minimum number of ZEBuses to be demonstrated on the street, relevant supporting infrastructures, maintenance and storing facilities, training of personnels, duration of demonstration, and operational and maintenance information keeping and reporting
   c. Well-defined periods for meeting each requirement
   d. Conditions and requirements for joint demonstration among multiple transit agencies.
3. A section on the requirements and specifications for conducting ZEBus demonstration for the Advanced Demonstration Project. Details are very much the same as the regulatory requirements and specifications listed in (2) except that the number of ZEBuses required for demonstration doubles that required by the Initial Demonstration Project. Transit agencies are given the flexibility to follow the single or joint path demonstration. The requirements for joint demonstration among multiple transit agencies differ from those established for the Initial

Demonstration Project. Credits for the demonstration of ZEBuses can also be identified in this section.

4. A section on the purchasing requirement for ZEBuses. There is a requirement for a certain percentage of purchase and lease agreements to be achieved within the specified period. Grace period is given before the implementation of the regulatory requirements. Further, a reward system which encourages early purchase and adoption of ZEBuses is in place. Purchase credits are also accrued for advanced demonstration of ZEBuses. The Regulation also provides provisions for reviewing ZEBus technology and the feasibility of implementing requirements of the credit system before a certain deadline.

ZEBus Regulation and NERA

A brief overview reveals that ZEBus Regulation displays some regulatory characteristics of NERA (see Table 2). To a certain extent, the ZEBus Regulaton is goal-oriented. Its objective is to encourage adoption and operation of cleaner fuel technologies for urban bus fleets in California, instead of forcing the transit agencies to comply with particular transport technologies. The regulatory goal is highly stringent. By setting the goal 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 for meeting the stringent target. 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 ZEBus Regulation.

Transit agencies which undertake ZEBus demonstrations or purchase of ZEBuses in advance are given credits or purchase credits. The earlier the demonstrations/purchase of ZEBuses, the higher the credits accrued. The positive incentive provides the impetus for transit agencies to develop advanced cleaner technologies early in exchange for more credits. Designing ZEBus Regulation in terms of well-defined phase-in periods ensures that transit agencies in California are given the flexibility to identify the cost effective technologies instead of being forced to adopt hasty and expensive solutions. Further time flexibility is given in the form of grace period assigned for demonstration. This allows transit agencies are given sufficient time capacity to develop the relevant capabilities that are needed for technological transition. The ZEBus Regulation is capability-enhanced. First, the option for joint implementation of ZEBus requirement facilitates inter-organizational learning and resource sharing and enhances the building up of innovation capabilities for individual transit agencies. Second, the requirement for ZEBus demonstration is complemented by California Fuel Cell Partnership (CaFCP), a voluntary programme initiated by the California state government. On the one hand, the mandatory ZEBus demonstration requirement provides a testing ground for transit agencies to evaluate the feasibility of running new bus technology, and to develop the essential capabilities for technological transition overtime. On the other hand, CaFCP provides an essential platform for partnerships and collaborations among a wide range of stakeholders. It facilitates the sharing of skills, expertise and resources among different stakeholders and provides the essential financial, infrastructural and technical support to help transit agencies kick-start the fuel cell bus demonstration on streets. Finally, the ZEBus Regulation provides rooms for stakeholder participation. Throughout the regulatory process, regular meetings between regulators and industrial stakeholders, and public consultations have been held. This opens up the opportunities for dialogue and communication, and relationship and trust-building between the regulated parties and the regulators.

NERA Regulatory Characteristics	*Evidence*
Goal-setting	The goal of encouraging the use and operation of zero-emission buses (ZEBuses) in California is established by CARB.
Stringency	High stringency. ZEBus Regulation requires that a certain percentage of buses purchased or leased should be ZEBuses before commercial ZEBuses are available. The Regulation requires transit buses to commit in the demonstration of a certain number of ZEBuses on street.
Certainty	Deadlines for ZEBus demonstration and well-defined phase-in periods for demonstration of certain percentage of ZEBuses 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 ZEBus demonstration programmes and options for joint implementation of demonstration and purchase/leasing agreements of ZEBuses are provided.
Incentive-driven	Credit award systems are provided to encourage early adoption of advanced ZEBus 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 ZEBus)
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.
Participatory	The regulator conducts extensive consultation with the transit agencies and other stakeholders, through regular meetings with the regulated parties and consultations with the public.

Table 2. Regulatory Characteristics of ZEBus Regulation

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

In the following, citing from the case of ZEBus Regulation introduced in California by California Air Resources Board, we demonstrate how NERA enhances the favourable innovation conditions that are needed for transit agencies to engage in ZEBus demonstration.

In the previous session, it has been argued that three favourable innovation conditions, namely, economic incentives, innovation capabilities, and stakeholder norms, attitudes and behaviours, determine 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 un-conventional ZEBuses such as the fuel-cell prototype require substantial financial investment in the short term, whereas profit-returns are not obtainable until the longer term. 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 financially unattractive. Hence, without a strong regulatory pressure, it is very difficult to push transit agencies to pursue the zero-emission technology and collaborate with the automobile suppliers and fuel cell technology developers. The guiding principle of ZEBus 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, ZEBus 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 TERA, ZEBus 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. ZEBus 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 ZEBus demonstrations. An evaluation report (CARB, 2006) on ZEBus Regulation showed that ZEBus 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 ZEBus 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. ZEBus Regulation is established with the goal to encourage development and commercialization of ZEBus technology (CARB, 2009c). A number of supporting policies have been in place in support of ZEBus. 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 ZEBus 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 ZEBus 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 CaFCP, ZEBus Regulation enhances the innovation capabilities of transit agencies by requiring ZEBus demonstration. The setting up of phase-in periods and ZEBus demonstration and constant reporting to the regulators helps transit equip themselves with the necessary capabilities towards the zero-emission pathway. ZEBus demonstration helps them familiarize with ZEBus development, operation and maintenance. The option that allows joint implementation is also a clear indication that ZEBus 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 ZEBus technologies and modify regulatory requirements.

Stakeholder norms, attitudes and behaviours impact significantly firm decision-making on technology change. The requirement for ZEBus demonstration undoubtedly encourages ZEBus technology testing and familiarization, and increases managerial and public receptivity towards the new technology. The ZEBus regulation has also been characterized by a participatory process that kick-starts dialogues and communications between public stakeholders and the regulators. Regular public workshops were held to review the ZEBus regulation. Information and ideas on ZEBus 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 ZEBus 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. 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 TERA which has repeatedly been considered to be ineffective in mobilizing companies to continuously improve their environmental performance due to its adversarial, inflexible and C&C REG 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 PD REG, 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 ZEBus Regulation introduced by CARB adopted in 2000, we argue that the 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 ZEBus demonstration projects. Considerable success has been achieved in the initial demonstration of ZEBuses. A total of seven ZEBuses, 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 ZEBuses 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 ZEBuses in California (CARB, 2009c). ZEBus 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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