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碩士論文

Master's Thesis

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以正當性理論與利害關係人理論分析台灣鋼鐵產業

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Abstract

Contemporary research on corporate social responsibility (CSR) highlights its disputed effect on firm profitability and the determinants of environmental disclosure. Largely missing from these accounts is a critical look at stakeholders — particularly agents in the public, market, and voluntary sectors — and how they influence corporate investment in environmental management systems (EMS). This study explores CSR trends in Taiwan's private-sector steel industry, focusing on small- and medium-sized enterprises (SMEs) with electric arc furnaces and contrasting them with the nation's flagship industry conglomerate, China Steel. The research suggests that without a crisis of legitimacy or significant stakeholder pressure — particularly government pressure and pressure to retain ISO 14000 certification — SMEs see little incentive (and high costs) to build an effective EMS. Also, contextual factors in Taiwan pose both problems and opportunities for sustainable initiatives. Specifically, environmental laws are modern and strict, but administrative capacity to implement laws is not uniform island-wide. Also, activists and localized self-help groups pay less attention to SME steel firms and spend more effort over controversial industries like nuclear power, high-tech manufacturers and petrochemical companies. Still, government and cross-sector alliances sometimes take an active role in subsidizing EMS and promoting research and development. Using a mixed methods approach within the critical field of political ecology, the research concludes that economic concerns drive SME steel firm behavior, with changes in the scale of EMS development coming into play only in favorable cost-benefit scenarios and typically with substantial pressure emanating from the private and public sectors.

Keywords: environmental management systems, corporate social responsibility, legitimacy theory, stakeholder theory, environmental governance

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AHSS	advanced high-strength steel
BAT	best available techniques
BSCD	Business Council for Sustainable Development
CDP	Carbon Disclosure Project
CO	carbon monoxide
CSC	China Steel Corporation
CSER/CSR	corporate social and environmental responsibility/corporate social responsibility
DJSI	Dow-Jones Sustainability Index
EAF	electric arc furnace
EIA	environmental impact assessment
EMS	environmental management system
EPA	Taiwan Environmental Protection Administration
GHG	greenhouse gas
GRI	Global Reporting Initiative
IDB	Industrial Development Bureau
ISO	International Organization for Standardization
KMT	Kuomintang, Chinese Nationalist Party
MOEA	Ministry of Economic Affairs
NCSD	National Council for Sustainable Development
NGO	non-governmental organization
NOx	nitrogen oxide
NPO	non-profit organization
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCDD/F	polychlorinated dibenzo-p-dioxins and furans
POP	persistent organic pollutant
RCRA	Resource Conservation and Recovery Act
ROC/R.O.C.	Republic of China
R&D	Research and development
SME	small- and medium-sized enterprises
SOx	sodium monoxide
SRI	socially responsible investment
TCSF	Taiwan Corporate Sustainability Forum
TEPU	Taiwan Environmental Protection Union
UHSS	ultra high-strength steel
UNFCCC	United National Framework Convention on Climate Change
VOC	volatile organic compound
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WSA	World Steel Association

1. Introduction

1.1 Motivation for Research

As Taiwanese society considers its status as a high-tech industrial powerhouse and its aspirations for formal diplomatic recognition, the issue of environmental protection hangs in the balance. The documentary film *Beyond Beauty: Taiwan from Above* (看見台灣) released in October 2013 highlighted this tension between industry and nature via airborne panoramas that showed the island's lush green wildlife juxtaposed with the muted colors of industry, bleeding outward along polluted waterways. This film caused a sensation when it first screened in theaters, breaking domestic box office records and taking home a Golden Horse Award for best documentary. It also brought about investigations into heavy industry players that were later forced to pay the maximum fines permitted by law and, in the case of Advanced Semiconductor Engineering Inc. (ASE), undergo criminal prosecution for illegally dumping wastewater and submitting bogus environmental monitoring data.

This newsworthy intersection between the culture industry, heavy industry and the government shows how dynamic environmental protection issues have become in modern-day Taiwan. Still, the heart of these issues runs deeper than the latest environmental scandal to appear in the media. In an economy built mostly of small- and medium-sized enterprises, Taiwan's environmental predicament is felt mostly in the accumulated impact of a myriad companies whose individual footprint might not merit much government concern. Especially as Taiwan phases out its economic past (centered on heavy industry) in favor of its high-tech present and future, traditional sources of pollution don't always receive enough attention from environmentalist actors. Particularly after undergoing decades of technological upgrades and environmental management system (EMS) renewal, the question of how heavy industry firms ultimately decide on their environmental protocols — what factors they consider and why — becomes crucial to understanding the power, potential, and paradoxes that confound ongoing efforts to make Taiwan a "green" island.

Steel production offers a good opportunity to study this timely issue. The steel industry was pivotal to Taiwan's early economic development and matured alongside its earliest regulatory successes like sulfur oxide (SOx) and nitrogen oxide (NOx) emissions standards as well as regulatory failures like dioxin control. Thus, steel production might be a microcosm of

the economic and regulatory environment in Taiwan's heavy industries more generally. The green potential of steel production also makes this industry the perfect target for research into corporate social responsibility (CSR) – unlike other heavy industries with no examples of cutting-edge green innovation.

As early as 2011, a small number of steel manufacturers in Europe have been certified Cradle to Cradle (C2C)[1]. C2C describes a manufacturing system involving only two types of materials: biodegradable materials (which can be returned to the "biological cycle" without harm) and materials that can be recycled infinitely (within a closed-loop "technical cycle") without degrading in quality or producing negative externalities (like waste). The creators of C2C see this model as a way of revolutionizing the manufacture of all goods in a sustainable future. So while Taiwan's small- and medium-sized enterprises (SMEs) might be far from the C2C ideal, that path has already opened to them through the example of others.

Generally speaking, the melting down of scrap material in small-scale electric arc furnaces (EAF) can produce steel for re-use while maintaining quality – an insurmountable hurdle in most plastics and paper recycling. The key environmental setback for most steel firms has to do with waste management. Still, steel (as a "nutrient" in the technical cycle) offers an exciting glimpse into a sustainable future. Iron and steel are the most recycled materials on earth and form the structural basis of new sustainable technologies (e.g., efficient vehicles, green buildings, alternative energy). Moreover, Taiwan has already earned an international reputation for sustainable steel production in the likes of China Steel, one of the oldest industrial giants on the island. The combination of momentum and potential from within society, within public sector environmental protection agencies and within the industry itself makes sustainable steel an exciting topic of research.

1.2 Research question and design

Understanding how companies make decisions about environmental investment helps gauge their level of commitment to environmental causes. Also, different stakeholders in society want to influence this decision-making process, and some of their strategies enjoy more success than others. This study asks the following question: To what extent do sector-based pressures (i.e., influence from the public, private and voluntary sectors) impact upgrades of environmental

[1] *See* http://www.sustainableinsteel.eu/p/544/cradle_to_cradle.html

technologies and practices in Taiwan's contemporary steel industry? In other words, this research organizes pressure on the EAF firm into three basic groups: pressure arising from government, from industry, and from civil society (communities, independent academia, the media). Then I tried to ascertain which kind of pressure has the greatest impact on companies.

Admittedly, these sector-based categories are not isolated wells of influence. Agents from multiple sectors often interact and cooperate on environmental initiatives, as the growing literature on public-private partnership can attest. For example, lawmakers may speak at press conferences organized by environmentalists, or experts from academia may test water sources for pollution and government agencies may rely on their data. To prevent any confusion, this categorization scheme focuses on the pressure point each sector can control. When water pollution data from voluntary sector experts forms the basis for a government *fine*, then this initiative belongs with the public sector. When the same data becomes the basis of a *civil lawsuit*, its influence emanates from the voluntary sector. The literature review includes a more in-depth explanation of stakeholder groups and tactics.

The primary unit of analysis for this research is small and medium-sized steel companies in Taiwan that use EAF. According to the Taiwan Steel and Iron Industries Association (TSIIA), EAF technology is the primary source of environmental impact from the steel industry in Taiwan, particularly with regard to waste management and air pollution issues. Thus, I distributed a detailed survey to the entire population (according to TSIIA records) of 21 EAF steel manufacturers. Since my list of EAF companies comes from an official source, however, this study does not incorporate data from "underground" companies, which operate illegally and beyond the present monitoring capacity of private- and public-sector regulators. Although I did not come across evidence to suggest that this kind of EAF facility exists, interviews with current public officials and environmental studies experts highlighted this general phenomenon. These underground plants, they asserted, cause more environmental damage than their lawful counterparts.

The survey asks for an inventory of EAF-related environmental technologies and practices based on the 2013 Best Available Techniques (BAT) reference document released by

the European Commission.[2] In addition, the survey measures corporate perception of pressure from pro-environment agents in each sector. I received a total of five complete responses from a pool of six total responses (not including China Steel), which amounts to about a 23.8% success rate. Since few companies responded, the large number of variables in the survey limits its usefulness as an instrument for unearthing trends in corporate decision-making. For such a small number of cases, it would have been better to operationalize fewer variables.

Another possible limitation of the survey is that companies might only participate if they feel secure about their environmental record. Fearing a potential public relations fallout after their responses reach the public, polluting firms might keep quiet about their activities. To try and counteract this bias, as well as to make up for the disappointing participation rate and better understand my topic, I also conducted in-depth interviews. I spoke with members of the public, private and voluntary sectors as well as academics before and after survey distribution. This report especially relies on 16 interviews with members of the voluntary sector (environmentalist groups and academics), steel industry representatives, government officials and industry consultants.

These interviews helped diversify the operationalization of survey variables by sector (e.g., emissions standards, enterprise environmental protection awards, and voluntary programs in the public sector) as well as explain intervening variable impact on firm upgrades (i.e., the impact of routine manufacturing upgrades). By casting a wide net to accumulate data from all sectors, this study seeks to employ the methodology of political ecology studies described by Little (2007). This method incorporates four main analytical tools/principles: an identification of socio-environmental actors (agents from the social and natural world), an emphasis on relationships, exploration of context, and focus on internal dynamics (procedures and/or flows of resources or lines of command).

To satisfy the requirements of this analytical paradigm, the environmental governance segment of this report details the socio-environmental actors involved in EAF steel production in Taiwan, from the ecological and technical context of EAF steel production — its impact on the natural world and the components of an optimal environmental investment scheme — to the

[2] Taiwanese environmental protection agencies use this same document to advise industry and craft regulatory policy for EAF facilities. The BAT serves as a kind of green manufacturer's wish list and includes the latest technologies designed to minimize the impact of production.

private, public and voluntary sectors whose activities impact (and are impacted by) corporate decisions to implement EMS. Next, the literature review section explores legitimacy theory, stakeholder theory, and other viable explanations for why firms engage in (or avoid) developing their EMS. Finally, the results and discussion sections organize the feedback from surveys and interviews in light of the preliminary research.

Importantly, this study does not succumb to the critique levied by Vayda and Walters (1999) against early self-styled political ecologists; these researchers apparently begged the question by assuming that organized politics had a key role to play in environmental change, and then they set out to prove it. In fact, unlike many studies in the field of political ecology, this research tackles a relatively uncontroversial issue in Taiwan's contemporary political scene – despite the important impact EAF steel production can have on public and ecological health. The following section about the significance of the research discusses this further.

1.3 Research significance

This study contributes to prior work in the political ecology field by examining a site of environmental conflict (industrial activity versus public and ecological health) that does not engage civil society groups in open, direct and political conflict with public and private sector actors. In other words, waste management and other environmental problems in Taiwan's steel industry have not captured the public's attention like issues such as nuclear power and untreated wastewater dumping by semiconductor and electroplating firms. In the course of my research, there has been little indication of a public scandal brewing in the steel industry, and this actually marks a departure from most subjects of inquiry in political ecology.

Most political ecology research emphasizes hot-button issues[3] involving polluting industries that are in conflict not only with the sustainability of the natural environment but also with groups at various levels of society (NGOs, neighborhood associations, regional governments, indigenous tribes, and more). It's important to develop a clear picture of how industries that fly largely under the public radar operate, especially in regions where heavy industry is still a chief contributor to economic development. Despite the emotional appeal of intense industry-society clashes, most industries worldwide do not bear the weight of infamy,

[3] For example, diamond mining in Africa, fair trade coffee plantations in Latin America, the destruction of mangrove ecosystems in the Philippines, etc.

and yet the cumulative environmental impact of factories that go relatively unnoticed amounts to a much greater impact than the few firms that endure pointed scrutiny. This study seeks to fill this knowledge gap in the critical field of political ecology — a methodologically strong field that needs a better understanding of "business as usual."

In addition, this study makes a contribution to the knowledge available in English regarding the specific forces at work in Taiwan's small- and medium-sized steel and iron enterprises and their relationship with the environment. This information is especially relevant considering the intensity of steel use in Taiwan per capita relative to other countries. Chang et al. (2002), comparing Taiwan with Japan and the U.S., concluded that Taiwan has the second highest per capita use of steel (to Japan), but steel demand and use were increasing in Taiwan whereas Japan was on a downtrend. Taiwan also superseded Japan and the U.S. with regard to intensity of steel use (defined as production/GDP), which Chang understands to be an indicator of Taiwan's relative inefficiency.

Furthermore, this work has practical significance for stakeholders in Taiwan who seek greater impact on industrial decision-making. The study isolates initiatives by sector while highlighting the activities of environmental agents, paying special attention to the unique limitations of institutions and groups. Thus, members of these organizations can leverage this insight to enhance their initiatives. Little (2007) says the following about the practical significance of political ecology research: "This knowledge … contains the potential for being appropriated by the very social actors involved, and may even promote the questioning of existing public policies and the proposal of new forms of action and public control." Moreover, local environmental policy wonks indicate that stymied progress in Taiwan can arise from a lack of mutual understanding across sectors and the poor communication that results; this is especially true for some environmental activists who lack an understanding of corporate motivators and limitations beyond "greed" and other unhelpful buzzwords. My own hope is that such activists will further empower themselves and their movement by harnessing more knowledge and a greater array of potential solutions – including technological solutions – in the fight against environmental degradation. Thus, this study's attempt to describe the circumstances of all members of EAF's "political ecosystem," while placing special emphasis on the steel production plants themselves, may serve as a jumping-off point to more informed and productive conversations about the nation's economic and environmental future.

2. Environmental governance and Taiwan's steel industry

The International Union for Conservation of Nature and Natural Resources defines environmental governance as "the means by which society determines and acts on goals and priorities related to the management of natural resources. This includes the rules, both formal and informal, that govern human behavior in decision-making processes as well as the decisions themselves."[4] According to the World Steel Association, steel is the most recycled material globally; it comes from processed iron ore and generates byproducts that affect natural resources like air and water. Electric arc furnaces are particularly popular worldwide because, by using recycled steel rather than iron ore, they require less capital and less energy than other facilities. For the purposes of this study, environmental governance involves stakeholders in the economic, political and social spheres influencing decisions to adopt and implement (typically capital intensive) environment-oriented technologies and procedures to control and mitigate negative externalities (Figure 1):

Table 1: ***Chief Aspects of Environmental Governance in EAF Steel Production***

Governance Factors	Components
Influence from the economic sphere (private sector)	-macroeconomic challenges -market/shareholder and customer pressure -industry associations -international industry standards -research and development alliances
Influence from the political sphere (public sector)	-central and local government regulations -voluntary initiatives -development assistance and subsidies -recognition schemes
Influence from the social sphere (voluntary sector)	-neighborhood self-help groups -nongovernmental organizations -media attention -expertise and activism from academics (not working on behalf of government or business)
Environmental management systems (technology and operations)	-expertise and information -accessible technologies and protocols -allocation of capital for upgrades -corporate decision making process, ethos
Environmental impact	-employee health concerns -public health issues

[4] *See* https://www.iucn.org/about/work/programmes/environmental_law/elp_work/elp_work_issues/elp_work_governance/

Environmental impact continued (negative externalities)	-global issues (especially global warming) -resource and energy conservation -waste control

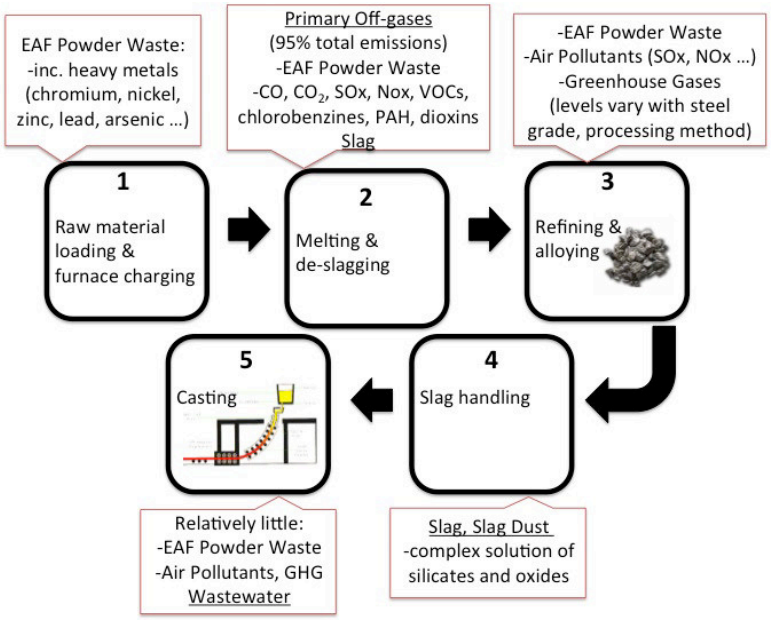
This section will explore each of the aforementioned parameters of environmental governance in turn, starting with an in-depth explanation of steel production in an EAF facility. This information contextualizes environmental investment by positioning it within a paradigm of day-to-day operations and forecasts potential areas for improvement. Next, a detailed look at what is at stake for the industry (i.e., the environmental impacts of EAF) illuminates the broader context of private sector initiatives for EMS development. The final two subsections discuss political/regulatory and social influences on EAF operations. Later, the efficacy of multi-sector influence on actual Taiwanese firms' EMS development will be explored in the results and discussion sections.

2.1 The steelmaking process with an electric arc furnace

Understanding in detail how EAF facilities produce steel makes it easier to grasp the inputs and outputs of the system and their environmental implications as well as the high level of expertise and capital required to make changes and improvements. As will be explored more thoroughly in the results section, cross-sector friction related to industrial upgrades (particularly when government regulators seek upgrades to older facilities) may result from or be exacerbated by company resentment over a perceived public sector failure to adequately measure the material constraints of an operation. The following section just skims the surface of the intricate industrial process of EAF steelmaking, implicitly drawing attention to the massive levels of sunk costs in particular technologies and existing methods of operation.

The process of producing steel with an electric arc furnace includes five complex phases: raw material loading and furnace charging, melting and deslagging, refining and alloying, slag handling, and casting. More precisely, the slag handling stage is not strictly a part of the steel-making process, but is actually a waste management task of crucial importance during each production cycle. Figure 1 depicts this production cycle and highlights the stages at which pollution and waste are generated. Section 2.2 describes the production and treatment of emissions and waste in greater detail, including a breakdown of EAF's solid and gaseous emissions and their respective impact on human and environmental health.

Figure 1: EAF steel production and pollution/waste generation



First, scrap iron must be collected as a base material (sometimes after undergoing a pretreatment process). This scrap material is often called "ferrous scrap," and can either constitute trimmings and discarded pieces from industrial steel molding and production, or it can be end-of-life consumer goods and parts. Sometimes direct reduced iron, or "sponge iron" — pellets of iron ore that were subjected to a fossil fuel-derived gas — may be added at this initial stage as well as "ferroalloys,"[5] which are concentrated nuggets of iron and some other desirable heavy metal like manganese, aluminum or silicon.

To bring about certain properties in the finished steel, the raw material must be mixed, or alloyed, with other elements at either (or both) the initial furnace loading stage or the refining/alloying stage. For example, add chromium (a highly toxic chemical) to make steel resistant to oxidation (rusting) — an immensely important feature of many grades of steel used in infrastructure development and transportation and other uses in a variety of climates with strict strength and longevity demands. Add aluminum to remove oxygen from the melted steel and prevent steel "aging" when under strain, add carbon for hardness and strength and add manganese to improve the mixture's hot working properties[6]. These preliminary additives can

[5] The symbol for iron in the periodic table is Fe, which comes from the Latin root word for iron, *ferrum*.

[6] *See* http://www.chasealloys.co.uk/steel/alloying-elements-in-steel/ for a list of common alloys and their properties.

be collected along with the scrap material[7] with the help of magnets or a mechanical claw and placed into an enormous metal "basket," also known as a charging box, which can be positioned above the kiln. The bottom of the basket will then open to allow the contents to pour into the melting area, "charging" the furnace (often with 50-60% of the prepared scrap at first, adding the rest after successive stages of melting).

Second, the scrap materials are melted by lowering a graphite (made almost entirely of carbon atoms) electrode or group of electrodes 200-300 millimeters above the scrap, suspended in the furnace. With a massive input of electricity, these electrodes conduct an electrical current that can vary between 42,000 and 50,000 amps[8] (compare that to a major home appliance that registers about 60 amps at most), generating an ongoing, ultra-hot plasma discharge from the head of the electrode and connecting with the head of the electrode beside it to form an "arc," or "u" shape approaching 3,000 degrees Celsius (and also producing a persistent, very loud crackling noise during the early stages of melting). As the melting process continues, the electrodes descend deeper into the scrap, often accompanied by an increase in power. To protect the furnace from radiation from the electrodes, many EAF firms simultaneously inject oxygen and carbon into the liquid metal at this stage, which in part transforms into carbon monoxide bubbles and a foam slag that also helps distribute the heat energy more efficiently as it shields the furnace walls from excessive damage[9]. The furnace itself is a refractory-lined vessel (coated with an alkaline material, like calcium oxide and magnesium oxide, with an extremely high melting point) that is typically equipped with water-cooled panels. The electrodes may also come equipped with a water-cooled system.

Before the heating process is fully complete, typically limestone and/or dolomite (a kind of "flux," to use the industry jargon) will be added to the mixture at temperatures around 1,600 degrees Celsius to produce slag, a waste product. Between 50 and 120 pounds (about 23-54 kilograms) per ton of steel is required. Lime is particularly adept at reducing the sulfur,

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[7] It is perhaps most common, however, to add ferroalloys later, during the refining stage, to minimize the amount of valuable additives lost during deslagging.

[8] An amp, or ampere, is a measurement of the amount of electrical charge, i.e. the number of electrons, passing a particular point in a circuit within a specific time period, with 6.241×10^{18} electrons per second constituting one amp.

[9] Injection of oxygen at this point has even more benefits such as thinning overall levels of carbon (decarburization) and removing sulfur and phosphorus.

phosphorus and silica from the molten metal. Slag is the result of these undesirable components binding with the limestone/dolomite additive and rising to the top of the heated mixture. Slag not only minimizes impurities in steel, it can also form a kind of thermal blanket to minimize heat loss during melting. After a while, the top layer of undesirable slag is poured out when the furnace tilts to the side and/or it gets raked off the melted steel during "deslagging." The creation and removal of different types of slag (designed to remove different undesirable elements) may happen several times depending on the grade and type of steel being produced. Importantly, the removal of slag into a pot or directly onto the ground below the furnace results in the production of dust and fumes, the latter of which is pulled into an exhaust system.

Third, the furnace tilts to pour the molten steel into a preheated container called a "ladle," where it is refined. Refining is a process of making a metal more pure (rather than changing its fundamental, chemical characteristics), for instance, by removing sulfur, phosphorus and excess carbon and/or dissolved gases like nitrogen and hydrogen from the molten steel. Steel refining alone can be conceptualized as a number of specialized steps — at different "ladle treatment stations" based on the technological and steel grade-specific capabilities of an EAF facility — and often involves the removal of oxygen in the latter stages, i.e. via a process of chemical deoxidation, adding fluxes and deslagging, or sometimes vacuum degassing. The refining stage is also a key point to add ferroalloys to enhance certain properties of the steel and further deplete its oxygen content chemically. Also, inert gases are injected into the ladle to stir the mixture and achieve an adequate level of homogenization, and ladle furnace equipment reheats the finished mixture to the appropriate temperature for casting.

Through successive stages of creating and removing slag, a process of slag handling and processing must be initiated to manage this kind of waste. If slag has been collected into a specialized pot, it must cool and solidify there (often with the help of water sprays). Some companies treat slag with silica, alumina and boron to make it easier to deal with. If slag was poured onto the floor, after it solidifies is must be crushed, collected and moved to a storage area with shovel loaders or excavator vehicles. Eventually this substance will be further crushed and processed and can be made into either material for construction (particularly road-building) or lime fertilizer. In Taiwan, independent off-site facilities must be contracted to handle slag treatment — except in the case of Dragon Steel, a China Steel subsidiary.

Finally, the liquid metal is evacuated from the ladle and casted (poured into molds and

allowed to cool and solidify) according to the company's or clients' preferred specifications. Before the 1960s, most steel firms poured the molten medal into permanent molds, one-by-one. Thanks to modern metallurgy techniques, a more popular method today called continuous casting works by pouring metal from a ladle through a vertical gas-tight refractory tube and into a "tundish," a special reservoir that allows the steel to continue to flow vertically at a controlled rate through parallel gas-tight refractory tubes before reaching water-cooled copper molds. With only the outer shell solidified, the steel is then pressed on a curve under a system of rollers and water sprays until it emerges horizontal as a parallel series of long strands of a particular size and width (different configurations exist with specialized machinery) and a mechanized torch cutter cuts each strand to size. This method saves on energy and water as well as reduces emissions. The European Commission's 2013 BAT report states that 90% of global steel is cast using the continuous method, which includes every EAF facility in Taiwan.

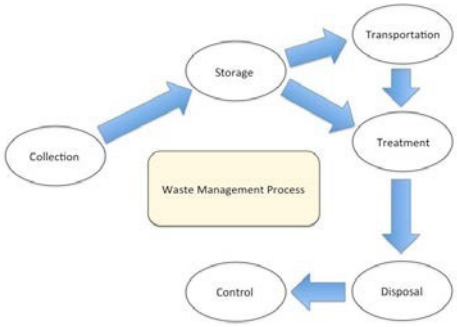
2.2 Environmental issues and mitigating technologies

The following paragraphs tackle the six main environmental issue areas associated with EAF steel production as well as the industry-standard environmental technology used to combat these problems (i.e., potential targets for EMS development). Generally speaking, the six environmental issue areas at stake are as follows: waste management, air pollution (including greenhouse gas (GHG) emissions), energy consumption, water use and spatial planning. With the exception of spatial planning, all these areas are included in the *Best Available Techniques Reference Document for Iron and Steel Production* published by the European Commission, which is the basis for the survey data I collected. These areas, however, are not equally important with respect to their levels of environmental impact. According to Ioana and Balescu (2009) and several of my interviewees, the main ecological issues with EAF steel production have to do with powder collection (waste management) and harmful gas control (air pollution). The following paragraphs will explore these environmental issues one by one as well as the industry standards and technologies used to mitigate their negative impact on the environment, beginning with the topic of waste management.

Waste management in EAF facilities targets industrial byproducts such as powders and slag. Tay Joo Hwa, researcher from the School of Civil and Structural Engineering at Nanyang Technological University in Singapore, describes industrial waste management as a process of at

least five (and sometimes six) steps.[10] The first stage involves a collection process. On a comprehensive scale, waste collection may be as complex and technology-based as specialized filtration devices that capture particles of a certain size as they are expelled through a drain or vent, or it can be as simple as office trash collection. The next phase involves storage of waste. Waste will accumulate in storage units until it is ready or able to move to the next stage. The third stage of the waste management process depends on whether or not a company processes its waste on-site. If the company has the capital and technical expertise necessary to process on-site, then the next stage is waste treatment. If not, then the waste in storage must be transported elsewhere for treatment; this is the case in Taiwan, where organizations like the Taiwan Steel Union Co. are charged with treating hazardous EAF dust.[11] After waste treatment, Hwa labels the final two stages "disposal" and "control." The most environmental form of disposal is through recycling and re-use; some of the mineral elements in EAF dust can be extracted and put to use in other industries as raw materials (through processes discussed later), as in magnetic metals from iron oxide dust. The control stage is rather vague in Hwa's report, but the term suggests maintenance, planning and care for the sites (e.g., landfills) where waste disposal occurs. Figure 1 illustrates the waste management process.

Figure 2: The waste management process



Source: Hwa, 2001

The biggest waste management hurdle EAF firms must tackle involves the prodigious amounts of powder, or dust, the industry generates. The release of airborne powder occurs at every stage of the EAF process, from loading to evacuation, and about 20 kilograms of powder is released per ton of steel (Boyanov & Baev, 2009). The fine powder contains a variety of heavy

[10] Hwa, J.T. (2001). Integrated report. In *Hazardous Waste Management Policies and Practices in Asian Countries.* Tokyo*:* Asian Productivity Organization.
[11] A 1999 amendment to the Waste Disposal Act called on SME firms to create their own waste disposal organizations and cooperate in waste management.

metals, including chromium, nickel, zinc, lead and more. Although heavy metals are naturally occurring in the environment, the higher concentrations of these substances through human industry make these substances highly toxic in the human body and surrounding environment. For instance, chronic exposure to hexavalent chromium has been linked to scarring and cancer of the lungs[12], and the banning of lead paint, lead pipes and tetraethyl lead (the key additive in leaded gasoline) after industrial lead poisoning incidents (involving brain, kidney and cardiovascular damage and death) and public health concerns shows the dangers associated with this element. Some EAF facilities can also test positive for arsenic in their waste output. In short, EAF dust is classified as a hazardous waste material because of its potential to leach into the ground and contaminate ground water and soil.

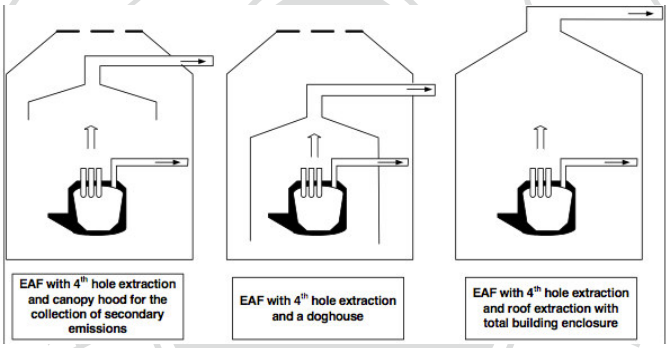
To counteract the negative impact from EAF powders, the global and domestic steel industry has implemented a variety of technology-based systems to a.) capture and filter emissions and b.) store and eventually extract useful components from these powders for reuse and, in some cases, to sell. In cases where extraction is not possible due to a lack of capital or technology and expertise, long-term storage is the only viable option from an environmental standpoint.

Emissions, composed of both gas and airborne EAF powder, are classified according to when they are generated in the steelmaking process. Emissions produced in the furnace during melting are called "primary off-gases" and account for 95% of total emissions — or about 10 times more gas than is produced after melting. Secondary emissions come about during scrap handling, charging and tapping as well as when fumes escape the furnace through the electrode openings or other leakage points. The steel industry at large has developed four main captivation systems (typically used in combination) to manage all steelmaking emissions: a "4th hole" system for primary off-gases as well as a canopy hood, a doghouse system or total building evacuation for secondary off-gases. The 4th hole system captures emissions from the melting stage using an opening in the furnace beside the area where electrodes protrude. Some older facilities still operate with only 4th hole extraction, disregarding secondary emissions collection entirely. A canopy hood can be installed above the furnace, charging area and/or refining area in a partially

[12] *See* Langrrd, S. (1990). One hundred years of chromium and cancer: A review of epidemiological evidence and selected case reports. *American Journal of Industrial Medicine, 17*(2): 189-214.

open-air facility to suck in secondary emissions. The larger the storage capacity of canopy hood systems, the greater their effectiveness in keeping secondary air pollution out of the atmosphere. However, these systems can be costly and consume power. A doghouse, or furnace enclosure, is a larger structure built over and mostly enclosing the furnace area inside a partially open-air facility. Doghouses passively direct fumes out a single opening to the filters and may also help to reduce noise emissions. A particularly large doghouse can capture emissions from charging as well. Finally, total building evacuation is possible when an EAF facility is totally sealed and fumes are collected from an opening in the roof area before they are filtered and released into the atmosphere. The European Commission recommends total building evacuation to capture the most comprehensive spectrum of emissions, especially those containing harmful PCDD/F. Figure 3 depicts the three main systems of air pollution collection.

Figure 3: Three air pollution collection systems



Source: European Commissions BAT guidelines adopted 2012

After emissions captivation through one of the systems above, gases undergo filtration, also referred to as purification or abatement. Purification happens when the offending particulate components of emissions are removed either through a wet process using high-energy scrubbers (that entrain particles in wastewater and remove them as sedimentation), a semi-wet process that applies water to off-gasses before filtering them through expensive electrostatic precipitators (machines that negatively charge particles in the air and magnetically attract them to metal plates) or a "dry" method using bag filters made of specially engineered textiles. Relatively low-tech bag filters are used in most EAF facilities around the world, although they are limited by their intolerance to very high temperatures. For this reason, the ducts that connect the gas inputs to the purification system are often cooled by dilution with air or with circulating water. Importantly, filtration removes most of the heavy metals from industrial off-gas with the exception of mercury, which cannot be eliminated by filtration or electrostatic precipitation. A

benefit of this popular dry method of pollution control is that it produces no wastewater in need of further treatment.

The extraction of useful heavy metals from collected EAF waste powder occurs thanks to advanced techniques using specialized heat-based processes (pyrometallurgical methods) and chemical solutions (hydrometallurgical methods). According to Boyanov and Baev (2009), zinc is the heavy metal most commonly extracted from EAF powders because zinc-coated galvanized steel is the most common form of scrap metal fed to EAF furnaces. However, the high amounts of halogen (nonmetallic elements that bind with hydrogen to form acids) in the powder can interfere with the extraction of zinc and other useful heavy metals.

One heat-based method of EAF powder refining and heavy metals extraction described in Boyanov and Baev begins with placing the powder in a specialized furnace and heating the mixture to 1200 degrees Celsius, which turns 95% of the chlorine and 59% of the fluorine into a gaseous substance. The Taiwan Steel Union in 1996 began implementing a Waelz Kiln procedure to process 50,000 tons each year of EAF dust to extract zinc oxides (Cheng, 2003). Finally, zinc may be leached through "washing" using a solution of water and Na_2CO_3 (molecules of sodium carbonate). Washing allows over 75% of the chlorine and less than 20% of the flourine to dissolve into the solution. Some technicians also recommend a preliminary stage of isolating some elements via magnetic separation.

In addition, EAF powders can also be reconstituted in other useful products such as glass-ceramics for use as building materials, road surfacing or refractory materials. With respect to slag, Taiwanese law states that it can be either deposited into specialized industry-use landfills or turned into road pavement. In the right proportions and using the appropriate methods, these waste products can enhance the strength and/or functionality of the recycled end product. Cheng (2003) stresses that EAF dust recycling is "critical" to efforts for cleaner disposal of the approximately 24,000 tons per year of powder produced by stainless steel facilities in Taiwan, especially since, as a hazardous waste, it cannot be thrown into the nation's landfills due to concerns over the leaching of heavy metals into soil and groundwater.

In short, while the extraction and/or reuse of useful materials from waste powders is beneficial for the environment and possibly the bottom line of the company that can sell the waste product, companies require either technical specialists to do the job in-house, or else enough capital to spend on getting an outside company to complete the job. A small enterprise

might lack the resources to get the job done, as was the case in Taiwan until recently.

A 2012 audit, jointly undertaken by the Taiwan Environmental Protection Administration (EPA) and the Industrial Development Bureau (IDB) and published on the EPA website[13], summarizes the huge environmental impact of EAF powder disposal in Taiwan. Every year the industry generates between 180 and 220 thousand metric tons of hazardous dust. As most EAF facilities are not equipped with on-site treatment operations, this industrial waste accumulates in storage containers with slag. Unfortunately, because of a general shortage in recycling and treatment centers catering to EAF refuse, the dust from EAF facilities, when aggregated, had totaled over 500,000 tons before help arrived. The EPA and IDB established four new high-capacity treatment facilities in three factories to gradually reduce the buildup and take care of future waste treatment needs.

Lastly, Chou and Fang (2005) highlight the worrisome environmental impact of improper waste disposal in the face of natural disasters. Their research monitored two million tons of steel slag deposited along the coastline in Southern Taiwan between 1984 and 1989, turning the seabed in that area to a mixture of sand and slag (a heavy-metal containing residue from steel production that's more gravel-like in contrast to EAF powder). Starting from 1990-1995, scientists measured relatively little change to the biological content on the seafloor at the dump site (notably, the site was not monitored during the early years of dumping), but this low-level impact changed gradually with a steady downward trend in crustacean populations ignited by Typhoon Gloria, which struck the study site in July 1996. Thus, in disturbing unstable collections of stored or dumped industrial waste, natural disasters can exacerbate the initial environmental damage from steel slag and powders. Surprisingly, however, the same group of scientists determined that slag disposal along the coast had positive impacts on communities of fish because it added to the complexity of their habit, providing more total surface area and small hollow areas for lifecycle activities. Notably, these studies mainly counted populations of species and did not take into account the impact of bioaccumulating heavy metals in the health of animals.

Typhoon Morakot in 2009 also caused disturbances for furnace slag waste disposal in Tainan. This powerful storm hit Chao Hsiang recycling center, leaving some steel waste exposed, and subsequent flooding transferred the waste into the surrounding environment. An

[13] http://epq.epa.gov.tw/project/projectcp.aspx?proj_id=1012145674

EPA deputy minister confirmed that the spill was likely behind chromium levels testing almost three times higher than the legal limit in the rice-producing areas of Houbi (後壁) Township, Tainan.[14]

The next major environmental issues involve air pollution and concerns over greenhouse gas emissions, two issues that go hand in hand. The gases that predominantly comprise EAF emissions include the two greenhouse gases carbon monoxide and carbon dioxide as well as sodium oxides and nitrogen oxides (Ioana & Balescu, 2009). In addition, production emits organic matter such as volatile organic compounds, chlorobenzenes, polychlorinated biphenyls, polycyclic aromatic hydrocarbons and polychlorinated dibenzo-p-dioxins and furans. The exact composition of polluting emissions depends on four things: the composition of the scrap metal, management of the melting stage, the refining process, and the length of time required for melting and refining a particular grade of steel. Since these emissions intermingle with the powders detailed in the waste management section, their capture/captivation and filtration process is nearly identical.

Although carbon is an important alloying component that increases the hardness and strength of steel, this element must be managed and often reduced from the molten metal mixture. This happens through oxidation, especially via a direct injection system of pure oxygen that combines with the carbon to form carbon dioxide (CO_2) and carbon monoxide (CO). Other than these molecules' significance as greenhouse gases in man-made climate change, CO can also have a direct impact on circulatory system efficiency in people and organisms exposed to the gas, even killing living things by inducing a state of hypoxia (reducing the oxygen carrying capacity of red blood cells) through carbon monoxide poisoning. Although there is little if any lethal risk from these greenhouse gas emissions in EAF plants, even in facilities supplementing their electrical energy with chemical energy via fossil fuel combustion, the inevitability of creating these climate-changing off-gases using current technologies and management techniques highlights the importance of continual innovation and technological improvement.

Like carbon, sulfur may be considered an impurity in melted steel and excess amounts must be burned away by injecting pure oxygen into the molten metal. An unintended side effect of oxygenation is the creation of sulfur oxides, which impact the environment by dissolving into

[14] Chao, V. (2009). Another case of slag contamination found in Tainan. *Taipei Times* (Nov. 17, 2009)

atmospheric water vapor and forming photochemical smog and acid rain — industrial byproducts that harm human respiratory health and threaten human infrastructure (by gradually dissolving stone structures) as well as acidify fragile ecosystems and hinder the ability of plants to photosynthesize. The relatively fewer impurities in scrap material versus iron ore makes EAF facilities relatively minor players regarding SOx emissions in the steelmaking industry; also, their mostly electricity-based power needs tends to reduce overall emissions from fossil fuel combustion. This will be explained in more detail with respect to nitrogen oxides.

Nitrogen oxides (NOx) come in three different forms with respect to steel production: nitric oxide (NO) nitrogen dioxide (NO_2), and nitrous oxide (N_2O). NO is by far the most prevalent of the three in EAF steelmaking, comprising as much as 90% of total nitrogen oxide emissions (Chan et al., 2003). These pollutants, together with SOx, are key components of smog and acid rain. The majority of NOx emissions in EAF facilities comes from the high-temperature oxidation of atmospheric nitrogen that gets pulled into the furnace through various openings (especially the passageway for removing slag). Nitrogen may also contaminate the oxygen supply of direct injection equipment, entering the hot furnace this way. Chan et al. (2003) states that the best techniques for nitrogen oxide abatement in steel production involve reducing the levels of nitrogen and oxygen in the furnace, by sealing the furnace and/or purifying the oxygen injection supply.

Other than high-temperature oxidation, two other chemical processes typically result in high industrial NOx emissions and both relate to the burning of fossil fuels. Most EAF facilities worldwide are powered principally from a three-phase utility-based generator, which means that they defer most of their fuel-related NOx production to power companies. However, many EAF furnaces supplement their electrode-based melting unit with oxygen-fueled burners, powered by natural gas. Natural gas combustion does form nitrogen oxides, although its advocates emphasize that it produces fewer overall emissions than the combustion of other fossil fuels like oil and coal.[15] In fact natural gas, composed mostly of methane, mostly releases carbon dioxide and water during combustion, but environmentalists often point to the gas-harvesting process of hydraulic fracturing (or "fracking") as the most worrisome aspect of this substance. Fracking uses pressurized, chemically treated water to break through rock deposits deep beneath the soil and release the odorless gas. This process releases methane — a much more powerful GHG than

[15] *See* http://naturalgas.org/environment/naturalgas/

carbon dioxide — into the atmosphere, while the chemically treated water can severely pollute groundwater and render valuable freshwater reserves unfit for human consumption.

Also of concern, volatile organic compounds (VOCs) result when "organic" carbon-based substances like solvents and paints are charged to the furnace. Since VOCs have a very low boiling point, they easily convert from a liquid or solid form to a gas. In the environment, VOCs are a key component in the formation of smog. Their effect on human health is gradual and difficult to measure, but manmade VOCs from off-gassing products in the home have been linked to respiratory problems, allergies and immune system deficiencies in infants and children.[16] The U.S.' Environmental Protection Agency warns that high doses of the most harmful VOCs can cause eye, nose and throat irritation, headaches, loss of coordination, nausea, liver, kidney and central nervous system damage. Some can cause cancer in animals.

Chlorobenzenes are common manufactured chlorine-based chemicals, especially useful in the creation of herbicides and pesticides, dyestuffs and rubber. With their high boiling point, they generally are a byproduct of melting scrap material that had been exposed to the chemical during its previous lifecycle. Chlorobenzenes are categorized as having a "mild to moderate" toxicity and a relatively short persistence rate in air (3.5 days), water (less than a day) and soil (several months). The Occupational Safety and Health Administration in U.S. regulates acceptable levels of the chemical in factories directly manufacturing and using it, whereas the airborne levels produced as EAF off-gas fall plenty short of these parameters. After exposure, chlorobenzenes may be excreted by functioning lungs or a healthy urinary tract.

Polycyclic aromatic hydrocarbons (PAH) are only comprised of hydrogen and carbon atoms that form different "aromatic ring" structures, and they tend to arise from the incomplete combustion of organic matter (including fossil fuels, wood, incense, tobacco and more). Although they can be formed naturally (e.g. in forest fires and, some physicists speculate, within the first two billion years of the Big Bang), high concentrations of PAH are considered a pollutant because they can harm human health and are persistent in the environment. Human exposure to hazardous PAH molecules tends to come from breathing polluted air, ingesting food or water contaminated with PAH, or making direct contact with contaminated soil or oils. Inside the body they spread and target fatty tissues and filtering organs like the liver and kidneys,

[16] Mendell, M.J. (2007). Indoor residential chemical emissions as risk factors for respiratory and allergic effects in children: a review. *Indoor Air Journal, 17*: 259-277.

exiting the body through waste matter within a few days. Studies of mice have shown the potential for reproductive system damage, birth defects and immune system impairment after exposure to high levels of PAH, but these symptoms have not yet been observed in humans.[17]

The ring structure or "weight" of PAH molecules determines their potential impact on human and environmental health. For instance, benzo[a]pyrene, a PAH molecule found in some degree in iron and steel industry emissions as well as coal tar and cigarette smoke, is mutagenic (able to alter the DNA of living cells) and highly carcinogenic. Yang et al. (2002) conducted a study to determine the PAH profile of emissions from steel and iron industries in Southern Taiwan, concluding that low-weight PAH molecules are most prevalent in both air and dust emissions, and dust includes "heavier" strains of carcinogenic PAH molecules (less than 1% of the total mass of PAH emissions on average). Compared to iron and steel facilities dependent on coal or heavy oil, however, electric arc furnace facilities generally produce less PAH molecules by more than a third.

The last two air pollutants fall under the "Dirty Dozen"[18] category of persistent organic pollutants (POPs). All POPs have adverse effects for human and ecosystem health, and both air and water can transmit them throughout an environment, even around the world (which creates problems of environmental justice, as POPs are created in one region or nation but then migrate to and cause problems in another). POPs tend not to break down but to persist in environments for long periods of time, often in the food chain. The Dirty Dozen became a distinct category of POPs in the run-up to a 2001 United Nations treaty signed by over 90 countries in Stockholm, Sweden, committing signatories to reduce or cease all production, use and/or release of the 12 toxic compounds. To this day the Stockholm Convention continues to pursue research, information sharing and international regulatory efforts dealing with POPs.

Polychlorinated biphenyls (PCB) are chlorine-based semi-volatile organic compounds. Their superb insulating qualities made them ideal for use as coolants and lubricants in electrical

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[17] United States Environmental Protection Agency Office of Solid Waste. (2008). Polycyclic aromatic hydrocarbons (PAHs) fact sheet. *Retrieved Sept. 21, 2014 at:* http://www.epa.gov/osw/hazard/wastemin/minimize/factshts/pahs.pdf

[18] The "Dirty Dozen" list is comprised of the following 12 pollutants: aldrin, chlordane, dichlorodiphenyl trichloroethane (DDT), dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (dioxins) and polychlorinated dibenzofurans (furans). It's interesting to note the ubiquity of the element chlorine in so many of these highly toxic compounds.

equipment, including transformers and capacitors. Heavy exposure to PCB in the workplace has been linked to skin conditions, and some studies point to possible liver damage and cancer of the liver and biliary tract. The World Health Organization (WHO) has identified a group of 12 PCB compounds relevant to EAF production that act like dioxins — carcinogenic compounds that bioaccumulate (especially winding up in the fatty tissues of animals) and are highly toxic, causing problems in human's and other organism's reproductive, immune and endocrine systems. Breastfeeding infants are particularly vulnerable to ingesting high concentrations of PCBs through contaminated breast milk. Also, according to the European Commission, the exact source of PCB in the steelmaking process is not currently known, but the pollutant might derive from scrap. As is the case with some other pollutants mentioned earlier, as higher quality scrap becomes available with the gradual phase-out of steel products made with now-regulated harmful additives, certain pollutants from EAF may become more rare and EAF emissions may become less harmful overall to the environment. In effect, EAF facilities can take a proactive stance toward producing higher quality steel as well as lessening their pollution emissions by regulating the quality of scrap material they process.

Unfortunately, filters, ESP and scrubbers are generally not efficient at removing PCB from off-gas; some tests conducted in Europe and reported by the European Commission found treatment systems that were wholly ineffective at abating the harmful substance. Thus, if PCBs arise in steelmaking emissions, they will inevitably make their way to the general atmosphere.

Polychlorinated dibenzo-p-dioxins and furans (PCDD/F), classified as aromatic organohalogn compounds along with PCB, are created in chemical reactions taking place especially during the melting phase of steelmaking. The creation of PCDD/F, also called *de novo* ("from the beginning" or "afresh, anew" in Latin) *synthesis*, involves molecules of chlorine (e.g. those molecules in PCB) binding with carbon and other elements under heat and pressure. These compounds are also known as dioxins, whose persistent and dire effects for human health and ecological systems were explained earlier.

The Stockholm Convention recommends an "off-gas conditioning system" to minimize this and other harmful substances before they reach the bag filter. An off-gas conditioning system involves the collection, cooling and ducting of potential air pollutants to the baghouse, and it must be molded to precise dimensions and involve sufficient gas circulation and techniques for bringing gas temperatures down to below 200 degrees Celsius — otherwise dioxins may actually

be created via chemical reactions within the conditioning system. Stockholm Convention documents also mention a different system of post-combustion afterburners (to combust carbon monoxide and hydrogen molecules and/or to de-chlorinate PCDD/F with temperatures over 800 degrees Celsius) followed by rapid quenching (cooling) as well as injections of absorbent, activated carbon or lignite coke upstream of the baghouse to further reduce off-gas pollution (the injections also decrease mercury pollution levels but may increase dust volume by as much as 2%). Unfortunately, this system requires supplementary fuel and yet another refractory lined combustion chamber. This somewhat reduced efficiency and the additional space and capital requirements of the method along with the inconsistent results[19] of post-combustion afterburners make these techniques sub-optimal for many EAF facilities.

Finally, baghouse/bag filters can effectively collect some large, gaseous compounds that become absorbed in dust, as evidenced by EAF powders testing positive for trace amounts of PCDD/F. Reducing powder emissions also minimizes PCDD/F pollution, according to Stockholm Convention documents.[20] The baghouse/bag filter stage ends a typical off-gas conditioning process, with the exception that continuous monitoring of off-gas and air pollution parameters — with an eye to continually taking steps to optimize the system — also generates positive environmental outcomes. Unfortunately, scrap preheating, while beneficial from an energy conservation standpoint, actually increases the production of PCDD/F as well as PCBs and PAH.

The continuous casting process described in the overview of EAF steelmaking cuts down on pollution emissions by shortening the time in which hot steel is directly exposed to the atmosphere. The less exposure time, the less opportunities for dioxins to form via de novo synthesis and the less likely particulate matter will evaporate from the molten mixture. Also, decreased fuel use from continuous casting limits the air pollution that would have resulted from intensified fossil fuel combustion. Finally, because continuous casting improves overall yield, the method reduces pollution from each phase of steelmaking by making more efficient use of raw materials, thereby cutting down on the number of furnace chargings required to produce the

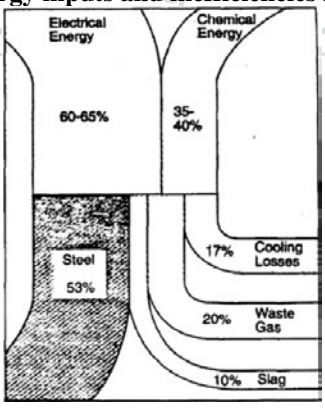
[19] The Stockholm convention paper (p. 208) mentions that de-chlorination methods were "not able to consistently meet the Canada-wide standard of 100pg TEQ/Nm_3."
[20] These documents also mention the possibility that "selective catalytic reduction technology" that decreases nitrogen oxides and PCDD/F emissions may one day become a standard technology in off-gas conditioning.

same volume of cast steel.

It's important to note that proper management and reduction of emissions not only affects the overall environmental impact of EAF facilities and compliance with environmental regulations, but improved production efficiency, particular through waste management and off-gas abatement and filtration practices, also translates into improved working conditions for EAF employees.

Beyond waste management, air pollution and GHG emissions, energy consumption is a topic of environmental concern with regard to EAF steel production, considering the massive inputs of electricity required above and beyond what is needed to generate a 3,000-degree electric arc. Indeed, approximately three quarters of the total energy required to operate an EAF facility is relegated to heating scrap.[21] Ferretti et al. (2008) explain the typical energy balance in an EAF system thusly: of total energy inputs, electrical energy accounts for 60-65% while chemical energy accounts for 35-40%; 53% of all inputs are efficiently harnessed to make steel while 17% is lost to cooling, 20% is lost as waste gas and 10% is lost as slag (Figure 3). They also describe three chief techniques for increasing the energy efficiency of EAF steel plants: plant design optimization, operational plant management (scheduling, maintenance, etc.), and optimized plant upgrades. As technology progresses over time, more and more advanced software allows EAF minimills to monitor more and more variables, simulate production changes and pinpoint areas for improvement. In general, though, the most energy savings derive from decreasing the time required for scrap heating and/or reheating at the ladle stage, utilizing scrap preheating procedures and increasing overall efficiency.

Figure 4: Energy inputs and inefficiencies in EAF plants



Source: Ferritti et al. (2008)

[21] http://archive.org/stream/technologystudye00ontauoft/technologystudye00ontauoft_djvu.txt

As was mentioned before, continuous casting is another EAF procedure that cuts down on the overall use of energy compared to the traditional method of pouring molten steel into permanent molds one-by-one. On the other hand, the continuous casting stage of steel production can also act as a bottleneck in the system if not properly managed, thereby requiring more energy inputs to reheat molten metals waiting to begin casting. Thus, Ferretti et al. (2008) devised a system of precisely calculated casting speeds and molten metal holding periods to increase the average electric energy savings in EAF facilities by 20%. Furthermore, continuous casting and other procedural innovations also have ancillary environmental benefits such as reducing air pollution emissions; for instance, the Stockholm Convention guidelines[22] suggest minimizing how long the furnace roof is open during charging, reducing air infiltration into the furnace and cutting down on operational delays as methods for decreasing energy use *and* production of PCDD/F.

One internationally popular technique employed over the last forty years to recover and use heat energy from hot gases released during steelmaking diverts these gases either to a charging basket or a charging shaft where they can preheat a new batch of steel scrap. This energy-saving technique is especially popular in countries with high electricity prices and has other benefits such as increasing the lifespan of electrodes, reducing emissions and reducing noise.

The fourth main environmental issue with regard to EAF steelmaking is water use and conservation. As was outlined above, EAF steelmaking involves a network of water-cooled furnace apparatuses and ducts. To minimize (and in some cases to nearly eliminate) the generation of wastewater and reduce overall water use, a closed-loop cooling system with recycled water (sometimes seawater) is recommended. Semi-dry and dry waste treatment systems are also preferable from a water conservation perspective. As for water directly exposed to various stages in the steelmaking process (like the spray systems during continuous casting), this water should undergo treatment before it gets discharged as effluent.[23] Engineering firms online offer many water treatment technologies and procedures, of course varying significantly in price and ranging from relatively simple filtration mechanisms to ion exchange, thermal

[22] *See* http://www.pops.int/documents/guidance/batbep/batbepguide_en.pdf, p. 208

[23] Interestingly, China Steel has initiated a partnership with the Kaohsiung City Government to create the Fengshan Sewage Recycling Project, which will replace raw water with water reclaimed from steelmaking operations.

degasification and reverse osmosis methods.[24]

Spatial planning issues in environmental governance involve the land and local resource use of steel industry facilities, especially when multiple facilities are highly concentrated in a particular area. Ma et al. (2007) states that "Kaohsiung City and Taoyuan County are the top two highest risk regions … in terms of carcinogenic risk (from chromium exposure) … because Kaohsiung City has the highest density of stainless steel factories and the second highest density of refractory factories; Taoyuan County has the largest number of stainless steel factories." Indeed, higher concentrations of steel mills and other industrial concerns like petrochemical plants and electroplating facilities, often grouped tightly together in industrial zones and science and industrial "parks," simply compound their environmental impact and place a greater burden on the ecological services provided by water and atmospheric resources.[25] Furthermore, new industrial complexes may pose a substantial threat to important local biodiversity, as was the case in the successful grassroots bid to stop the development of Binnan Industrial Park (濱南工業區), which would have included an integrated steel mill, in Tainan on fragile wetlands that served as the winter habitat for the endangered black-faced spoonbill (*Platalea minor*). Figure 5 shows a map of Taiwan with black stars representing the general locations of EAF steel minimills within particular counties in Taiwan. Figure 6 names the types of air pollutants regularly recorded by air quality monitoring centers in mainland China[26] as well as meteorological data collated from the Weather Underground and Yahoo! forecasts; in addition, a color-coded guide shows how the region-specific data (Figures 7-13) reflects the varying impact of pollutants on human health. Figures 7-13 show the air quality index measurements (reflecting a two-day period ending Tuesday, Aug. 18, 2015) for areas in Taiwan, from areas with the highest concentrations of EAF

[24] For example, a European firm PSE Engineering markets 15 industrial water treatment systems and notes at least three clients internationally that required closed-loop and open-loop water cooling and treatment systems for steelmaking and continuous casting facilities. *Source:* http://www.pse~eng.de/en/services/water_technology/process_cooling_water/process_cooling_water.html

[25] This phenomenon is especially egregious considering the yearly cases of illegal industrial waste treatment from these zones, typically from electroplating and petrochemical firms that construct underground pipes to dump effluent into nearby water sources, causing catastrophic consequences for agriculturalists and ecosystems downstream.

[26] The Beijing Environmental Protection Monitoring Center (北京市环境保护监测中心) and the U.S. Embassy Beijing Air Quality Monitor **(美国驻北京大使馆空气质量监测)**

activity (Kaohsiung, Taoyuan, Tainan, Changhua, Miaoli) to areas with the lowest concentrations (Ilan and Taitung, see Figure 5). In addition, meteorological data like temperature, humidity, and wind levels suggest conditions in which more people might be exposed to pollutants during outdoor recreational activities as well as conditions in which pollutants might circulate less (in high humidity) or more (with strong winds).

Figure 5: Map of EAF locations in Taiwan

Figure 6: Two keys for deciphering air quality index data (Figures 7-13)

PM2.5	Fine particulate matter
PM10	Respirable particulate matter
O3	Ozone
NO2	Nitrogen dioxide
SO2	Sulfur dioxide
CO	Carbon monoxide
UVI	Ultra-violet index

AQI	Air Pollution Level	Health Implications
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.
300+	Hazardous	Health alert: everyone may experience more serious health effects

Figure 7: Air quality index for Xiaogang District, Kaohsiung (Aug. 17-18, 2015)

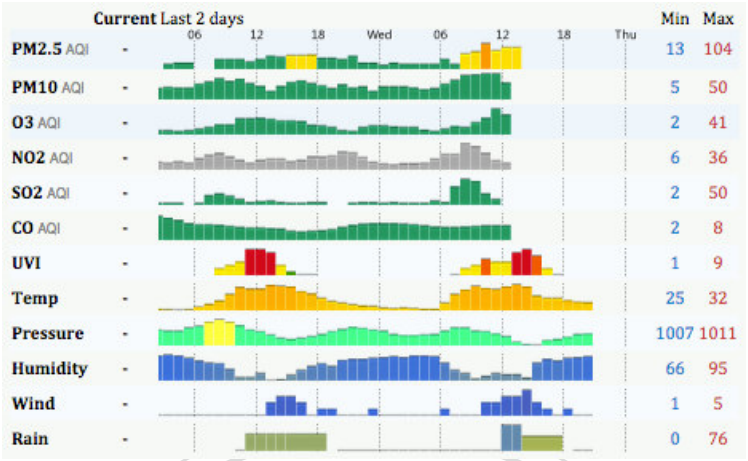


Figure 8: Air quality index for Taoyuan (Aug. 17-18)

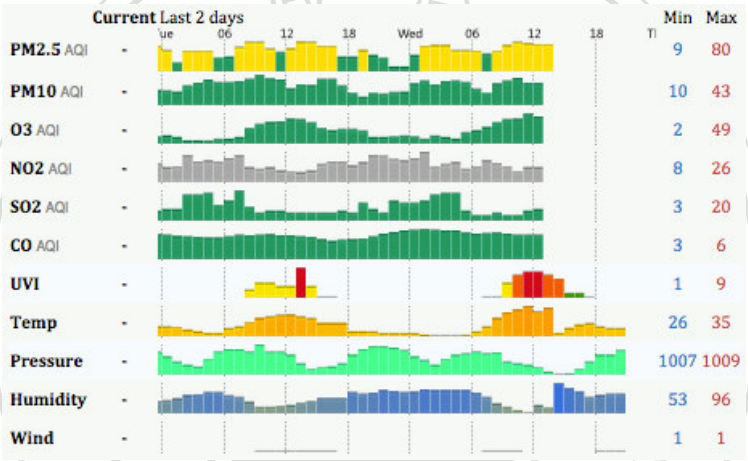


Figure 9: Air quality index for Tainan (Aug. 17-18)

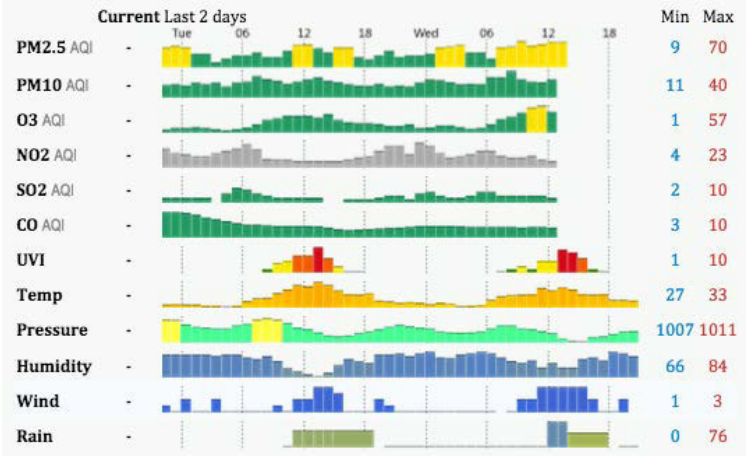


Figure 10: Air quality index for Changhua (Aug. 17-18)

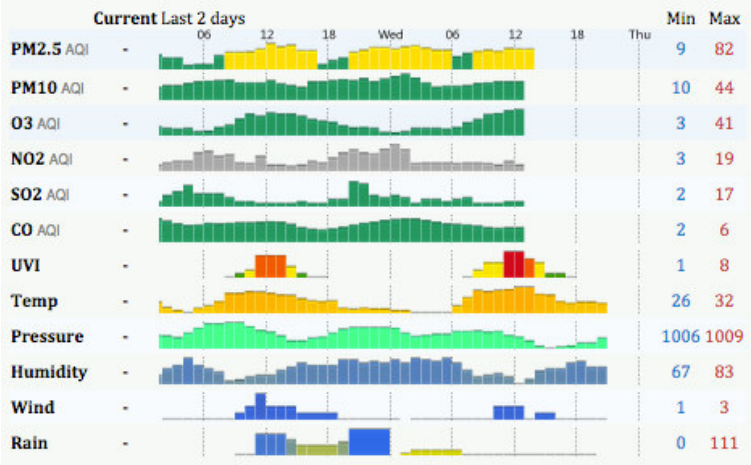


Figure 11: Air quality index for Miaoli (Aug. 17-18)

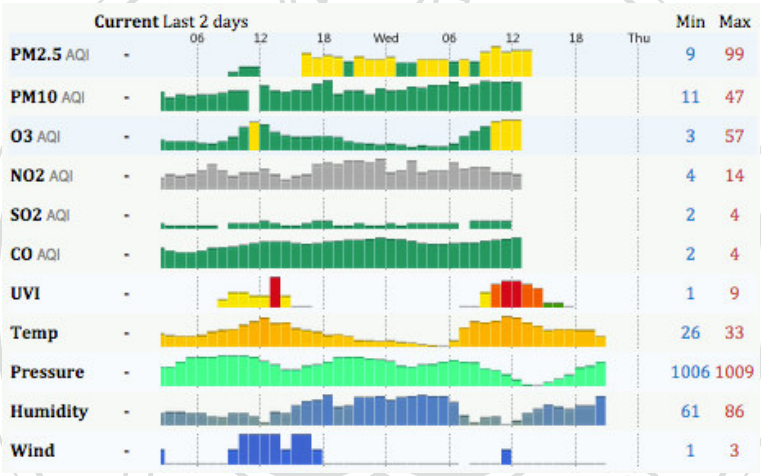


Figure 12: Air quality index for Ilan (Aug. 17-18)

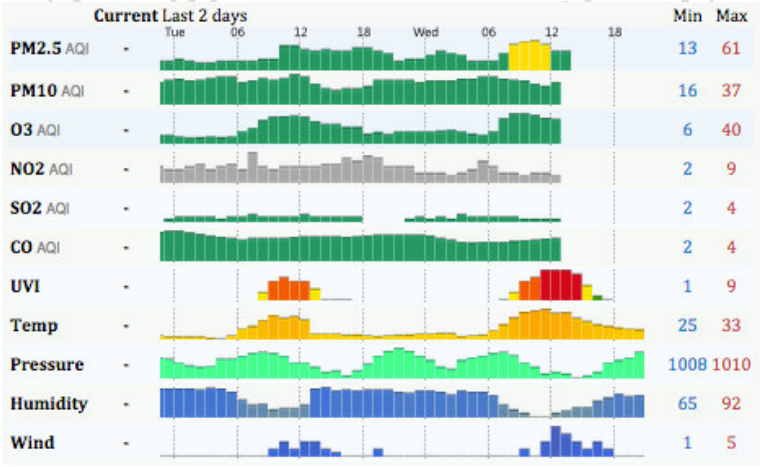
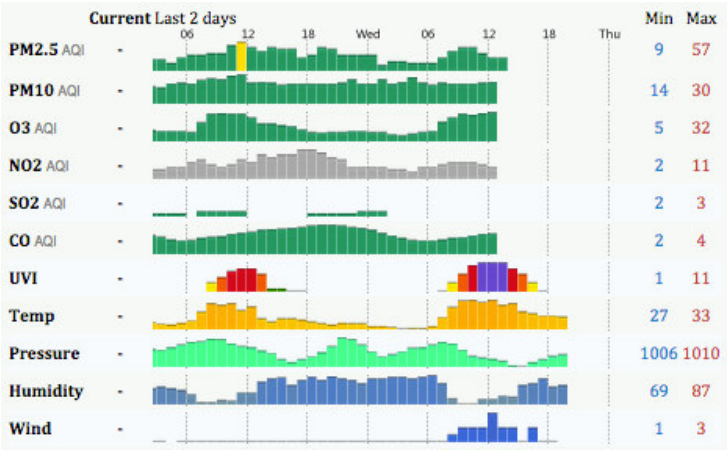


Figure 13: Air quality index for Taitung (Aug. 17-18)



2.3 Steel in Taiwan and private sector environmental initiatives

To understand the pressures, incentives and resistance to make sustainable steel, it's useful to consider the history of the industry in Taiwan. Of course, an environmental management systems focus did not emerge worldwide until well after the Taiwan steel industry's beginnings in the 1940s. Still, the industry's first economic networks form the groundwork for global market pressure (macroeconomic challenges) and cross-sector influence in the present. Furthermore, this section delves into contemporary private sector institutions and initiatives that serve as an impetus to and standard for environmentally responsible EAF steelmaking: the Taiwan Steel and Iron Industry Association (TSIIA), International Organization of Standardization (ISO) certification and research and development alliances.

In addition, this section briefly describes some private sector programs that affect steel sector leaders and large-scale operators in Taiwan; since EAF only entails steel recycling on a relatively small scale, these firms are not directly exposed to certain macroeconomic trends (for instance, iron ore pricing[27]), and they also might not have as much access to capital and human resources. As such, EAF firms in Taiwan typically do not participate in more cutting-edge initiatives like the following: the Taiwan Business Council for Sustainable Development, the

[27] However, this is currently a subject of debate in the industry, as an article published on Oct. 24, 2014 states, "Electric arc furnace (EAF) steelmakers no longer have the upper hand over their integrated steelmaking counterparts in terms of raw materials costs, according to Steel Dynamics Inc. (SDI) president and CEO Mark Millet." *See* *http://www.steelfirst.com/Article/3393432/Plunge-in-iron-ore-cost-dulls-EAF-mills-competitive-edge-SDI-ceo-says.html*

Global Reporting Initiative (environmental disclosure, monitoring), the Dow-Jones Sustainability Index, the Carbon Disclosure Project and investor governance networks. Still, these initiatives signal trends that are taking off in global industrial EMS, trends that may one day trickle down to small- and medium-scale operations, just as the ISO 14000 series did. The following paragraphs track the rise of all these initiatives from Taiwanese steel's humble beginnings in the ship recycling industry.

Taiwanese steel production emerged during Japanese colonization, and the first mills helped satisfy the military needs of Japan. These mills reprocessed waste steel using electric furnaces, with raw materials taken from the fallen targets of Allied bombings during WWII. In particular, bombings in Kaohsiung Harbor sunk several military vessels that would inadvertently initiate the first steel boom in Taiwan.

By the end of WWII and Japanese colonization, Taiwan came under the official control of the exiled Chinese Nationalist Party (中國國民黨). The nationalists, popularly known as the Kuomintang or KMT, set forth a plan in 1947 to salvage more downed ships in Kaohsiung Harbor to clear the port and provide the raw material for increased outputs of recycled steel. Ship scrapping quickly became a powerhouse of domestic economic productivity, and in 1965 the KMT government released a new plan to import more old ships from elsewhere. During this time, the Taiwan Steel and Iron Association (TSIIA) emerged to bring steel plants together and develop the industry fed by so many decommissioned vessels.

TSIIA emerged in 1963 to enhance the development of the steel industry through inter-firm cooperation. Since the early years it has coordinated a number of working groups to isolate discrete aspects of steel industry operation for research, development and standardization (early working groups include the wire rod group, the pig iron group and the casting steel and tin plate group). TSIIA also acts as a bridge between public sector policymaking and industry insiders, communicating policies to its membership and negotiating new regulations with policymakers. The organization also works to supplement steel firms' in-house research on international steel production, sales and inventory, to attract foreign buyers to Taiwan and to organize professional development and socializing opportunities for members. On June 7, 1985 they founded the Pollution Prevention Committee, and in 1996 they established the Industry Safety and Environmental Protection Committee. TSIIA's current membership of 240 companies includes not only steelmaking firms but also more downstream manufacturers.

While TSIIA was picking up steam in the '60s, development in the steel industry was accelerating along with the national economy. By the1970s, as Taiwan's "economic miracle" began to attract worldwide attention, the industry had disassembled more than 200,000 tons of super tankers. They led the world in this activity, generating approximately two thirds of the global volume of disassembled ships. Ship disassembly also provoked a flood of foreign exchange into Taiwan's economy, greasing the wheels for long-standing industrial relations internationally.

Many of Taiwan's first successful private steel companies, including Tung Ho Steel (established in 1962) and Feng Hsin (1969), started by buying scrap metal from ship disassemblers. To meet increasing demand over time, firms also began importing the raw materials for processing steel from ore in more advanced facilities. Between 1971 and 1991, a boom in civil construction[28] created a windfall for steel companies. Transportation vehicles and infrastructure and national defense equipment were also prominent markets at the outset. Still, several firms gradually shifted their output from infrastructure components to small parts and appliances. Outspoken domestic criticism for the Taiwanese steel industry's environmental practices was rare if it existed at all during the industry's initial boom period. On the contrary, the industry embodied Taiwan's ascent to global recognition for its economic miracle, and Taiwanese youth competed intensely for work opportunities in the most powerful companies. Among these were firms emerging from the KMT-initiated Ten Major Construction Projects (十大建設) from the 1970s. Among the ten, the nation built its first integrated steel mill equipped with a coke oven and blast furnace that was capable of producing the highest quality steel. This marked the foundation of the China Steel Corporation.

The China Steel Corporation (CSC), since its inception, has regarded itself as a step forward in Taiwan's industrial development. In contemporary times, along with its subsidiaries, the China Steel Group competes with top international environmental management systems.[29] It

[28] Construction continues to be a major domestic consumer of steel to this day, especially with a real estate bubble forming in the north in spite of government action (e.g. a luxury tax and penalties for holding on to vacant properties) to quell the tide and put a halt to skyrocketing prices.

[29] Wu I-Min of China Steel's Office of Energy and the Environment states that "CSC wishes to become one of the most environment-friendly steel companies in the world … However, all

is among the top 20 largest steel producers worldwide. Before its ascent to worldwide recognition, however, CSC paid huge sums to send Taiwan's best and brightest abroad for training. From the initiation of the Ten Major Construction Projects in 1974, it took four years for CSC to begin production and even less time to send foreign engineering consultants back home. Moreover, in addition to CSC's developing network of commercial ties, the company also engaged in transnational technology-sharing projects with steel plants in Indonesia, Malaysia, and South Korea. The privately owned company transferred into public hands in 1977 and was re-privatized[30]18 years later.

Besides large corporations like the CSC Group, however, the steel industry boom also gave rise to more small- and medium-sized enterprises. Since the island has no domestic source of iron ore, most raw materials come in the form of end-of-life products with steel components. The EAF technology capable of processing this raw material is also sufficiently simple and compact (relative to larger firms' integrated steel mills that work with ore), creating a lower barrier of entry into the market for smaller competitors. While Taiwan was engaged in its first stages of development, these SMEs could primarily focus on domestic demand. As globalization took hold and domestic demand lessened, however, SMEs joined their larger steelmaking counterparts to produce for export. Still, as companies grew to rely more and more on the global economy, they had to conform to an ever-evolving set of regulations and certification schemes. Over time these protocols adopted more rigorous standards for corporate environmental management.

The most prominent and widespread private-sector regulatory authority is the International Organization of Standardization (ISO). Unlike governmental regulatory bodies, the ISO operates by having representatives from national standardization bodies negotiate and promulgate an international system of expectations for all kinds of business operations. Rather

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investments need to consider economic, technical, and practical feasibility," (personal communication, June 17, 2013). He adds that all CSC Group members must earn ISO certification. The website for the World Steel Association (WSA) (formerly the International Iron and Steel Institute) promotes CSC as a case study in corporate sustainability. *See* http://www.worldsteel.org/steel-by-topic/sustainable-steel/members-reports.html.

[30] The ROC government still controls between 20-23% of shares. Long-standing government affiliation might even stimulate enhanced government pressure to go green; in its struggle for greater political recognition worldwide, Taiwan's public sector would hesitate to collude with big-time polluters.

than directly penalizing firms that fall short of standards, ISO affects corporate reputation via a certification scheme. Although formal ISO certification is voluntary, given the international legitimacy of the ISO mechanism, companies that either fail to receive or lose their certification for a set of ISO standards lose significant credibility in their industry and will likely be barred from trade due to market pressure and/or ISO-referenced government sanction. The certification process itself is decentralized from the main administrative body in Geneva, Switzerland and delegated to independent agencies in each participating country.

The ISO got its start at a multinational conference in London in the 1940s (although its predecessor, the International Federation of the National Standardizing Associations, was active between 1926 and 1942). Still, it wasn't until 1971 that the organization convened its first committee on environmental issues (specifically air and water quality). By the mid-1970s, European ISO representatives started spreading the ethos of industrial and technological standardization to China, Japan and elsewhere in Asia. In 1987 the ISO started implementing its quality management standards, and this preceded another process-oriented set of standards promulgated in 1996: ISO 14000.

The ISO 14000 series emerged in response to the 1992 Rio Summit on the Environment (also known as the Earth Summit, or the United Nations Conference on Environment and Development). ISO 14000 describes a set of guidelines for creating a corporate EMS, and the standards apply to industrial processes rather than merely the products they create. In this vein, ISO 14000 does not prescribe any explicit performance targets. Rather, it is up to firms to continually set new and personalized environmental targets based on their EMS protocols.[31] The Plan-Do-Check-Act cycle is a common shorthand for this process. Generally speaking, ISO 14000-certified businesses must monitor and disclose their environmental impact, set goals to minimize that impact (See Table 2), comply with national environmental regulations and continually improve. Although corporate environmental goals will vary under ISO 14000, the series helped form a standard of comparison for corporations implementing EMS — whereas before the advent of the series, each organization created its own system based on its individual environmental ethos, principles and methodology. Typically, steel firms producing for export display their ISO certification prominently on building facades, websites, and public relations

[31] Within the ISO 14000 series are standards for environmental auditing, life cycle assessment, environmental labeling and environmental performance evaluation.

material.[32]

Table 2: Example EMS improvement objectives and targets for EAF facilities

Objectives	Targets
Energy and Water Use	
Reduce total energy consumption.	Meet company business plan energy reduction goal of 10% normalized for production by January 2006 using 1999/2000 baseline numbers.
Investigate water-use reduction.	Complete study by January 2005.
Point Source and Fugitive Air Emissions	
Reduce visible melt shop roof emissions to meet new standards (6% Opacity).	Reduce visible emissions from the melt shop roof by 15% by May 2005 based on 1999 baseline.
Reduce mercury emissions.	Reduce mercury emission from the EAF Melt Shop due to mercury in auto scrap (by working with scrap suppliers) by 30% from 2002 baseline levels by July 2005.
Process Wastewater Discharge	
Reduce process wastewater discharge zinc levels.	Reduce daily average zinc concentrations from 5mg/L to 4mg/L by January 2005.
Storm Water Discharge	
Improve storm water discharge quality.	▪ Investigate improvements in storm water collection and filtration system by January 2006. ▪ Investigate effectiveness of additional best management practices by January 2006.
Hazardous and Non-hazardous Wastes	
Improve EAF's Mill Scale recycling rate.	▪ Achieve recycling rate of 80% of mill scale generated by December 2006. ▪ Achieve recycling rate of 40% of mill scale dirt/debris in south scrap yard by December 2006.

Source: Steel Manufacturers Association: Environmental Management System Guide (U.S. Environmental Protection Agency Archive Document: May 2005), *http://www.epa.gov/sectors/sectorinfo/sectorprofiles/ironsteel/02_Section_I.PDF*

From a macroeconomic perspective, rising labor costs, weakening domestic demand[33], increased competition worldwide and trade protectionism in key overseas markets started to shift many operations outside of Taiwan starting in the early 1990s. Taiwan's participation in a preferential trade agreement with China in 2010 — the Economic Cooperation Framework Agreement (ECFA) — exacerbated this problem since it became easier than ever for Taiwanese companies to escape to mainland China where labor costs were cheaper and regulations more

[32] Corbett and Kirsch (2000) state that ISO's quality and environmental certification is sometimes criticized for being too vague and too easy to acquire, especially in Asian countries. Referring to Taiwan as a case study, the authors contest this view by saying that although the central government has provided some subsidies to help certain SMEs cover the costs of certification, the standards are applied in Taiwan just as rigorously as in other countries. Furthermore, the authors interview a Taiwanese industry insider who confirms that companies may obtain EMS certification relatively easily when their environmental goals are low-hanging fruit, but it is much more difficult to stay certified in the long run.

[33] A 2013 working paper produced by the Ruhr-Universitat Bochum (RUB) Department of Economics in Bochum, Germany titled "Long Term Trends in Steel Consumption" found that steel demand increases in the initial stages of national economic development and then enters into a period of decline after the country hits a particular level of per capita income. The authors note that in their sample of "emerging economies," Taiwan was the only case that had already entered a stage of declining demand. *See http://www.rwi-essen.de/media/content/pages/publikationen/ruhr-economic-papers/REP_13_415.pdf*

relaxed. Mergers and acquisitions of steel plants also became more and more common on the world stage at this time, a fact that unsettled traditional trade networks and benefitted consolidated enterprises with more purchasing power for raw materials and larger distribution capabilities. Also, the need for Taiwanese steel firms to internationalize increased with outsourcing (generally, the 65% of companies currently manufacturing steel are export-oriented). Reporting on these macroeconomic trends in 2013[34], Secretary General of TSIIA Jerry Huang gave the following exposition:

> "In the beginning of this year, our government launched several incentives to stimulate investment, such as encouraging overseas Taiwanese corporations to return and invest in Taiwan. It was expected that these incentives would stimulate domestic employment and consumer confidence and increase imports. Unfortunately, first quarter 2013 performance did not live up to expectations. This, by the way, is a main reason for the government's recent revision of the GDP growth target."

In addition, a global oversupply of steel, growing competition from China, Japan and Korea, and unstable prices for raw materials[35] compound these macroeconomic trends. Shifting energy costs in competing countries (for example, decreased costs in the US after shale oil) also make for a challenging market. To combat the resulting period of relative economic stagnation, Taiwan's steel industry has begun to implement some strategies with implications for the development of environmental management systems.

One of these strategies is the formation of research and development alliances. China Steel's website describes the company's affiliation with "downstream steel companies, universities and research institutes" to enhance its production methods and end products. Some of these alliances are aimed at the proliferation of green technology in Taiwan, such as the "R&D alliance for eco-friendly processing of wire rod."[36] Among companies using EAF

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[34] These remarks were taken from a prepared speech regarding steel and iron industry performance in 2012 and forecasts for 2013, delivered to international steel industry representatives at the end of the first financial quarter in 2013.

[35] The Bloomberg article "Steelmakers seen hurting profits as sales chase dents prices" published Aug. 27, 2014 describes how steel firms are operating at 75-percent capacity on average internationally (80 percent in the U.S.) in an attempt to increase sales. This strategy, however, depresses the price of steel and decreases overall profitability in an era of ebbing demand and increased Chinese exports (as of September, 2014 saw a 33-percent increase in Chinese steel exports from the year before).

[36] *See* http://www.csc.com.tw/csc_e/ts/tsMain3.html

technology, in 2010 Dragon Steel publicized its use of the European PRIMUS technology to recycle dust and sludge. Dragon Steel is a China Steel subsidiary. TSIIA Secretary General Huang had the following to say about research and development alliances in Taiwan.

> "Our steel mills also try to do their best to foster cooperation throughout the supply chain. Steel mills are increasingly working together with downstream steel consuming manufacturers on R&D to develop high-quality steel products. Sustainable management is also becoming a big concern to run the steel business in Taiwan. High-value special steel is an area of promising growth that is now an active focus of government, university and manufacturer R&D cooperation."

In addition, like CSC's early technology-sharing efforts, TSIIA notes that Taiwan is once again reaching out to Southeast Asia to collaborate in overcoming global macroeconomic challenges.[37]

Throughout all stages of development in Taiwan's steel industry, continuous advances in technology brought about environmental (and economic) gains industry-wide. For example, steel plants experienced a 21-percent reduction in raw material inputs necessary to produce 100 kilograms of steel between the 1970s and 2010,[38] and energy consumption has decreased by more than double that figure in the same time. Less raw materials use also translates into reduced greenhouse gas emissions. Another cause for decreased GHG emissions occurs further down the production line: new advanced and ultra high-strength steels (AHSS and UHSS) are lightweight and strong, allowing for the manufacture of vehicles that consume less fossil fuels. Stronger grades of steel also allow for more efficient reuse.

Finally, the following paragraphs briefly describe the new wave of private sector initiatives for environmental management. China Steel has adopted each of these programs and protocols, but the initiatives have not yet penetrated the majority of small-scale EAF firms. First, the Business Council for the Sustainable Development of Taiwan (BCSD, 企業永遠續發展協), a nonprofit, was founded in May 1997 to encourage cross-sector and multi-industry partnership to

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[37] *See* Wu and Hsu's (2001) article "Towards a knowledge-based view of OEM relationship building: Sharing of industrial experiences in Taiwan" for a more comprehensive view on the role of transnational partnerships in Taiwan's domestic industrial development.

[38] *See* Yellishetty et al. (2012) "Iron resources and production: Technology, sustainability and future prospects" Available online at http://cfsites1.uts.edu.au/find/isf/publications/yellishettyetal2012ironresourcesproduction.pdf

promote corporate sustainability. Specifically, the BSCD has collaborated internationally[39] and with the central government to put forward a set of definitions and indicators for achieving "eco-efficiency," a strategy for GHG reduction and energy issues, corporate social responsibility schemes, environmental disclosure protocols and socially responsible investment (SRI) plans. China steel is among the large-scale companies that publishes white papers and lobbies the government under the auspices of the BSCD, and the organization's most recent (2010) "Emerging 800" list of environmentally responsible businesses includes China Steel, Chung Hung Steel, Feng Hsin Iron and Steel and Tung Ho Steel.[40] BCSD also maintains a database of annual environmental and sustainability reports published by steel and other industries. In 2008, the group launched the Taiwan Corporate Sustainability Forum, a platform for non-BCSD members to join members and discuss CSR best practices.

Second, the Global Reporting Initiative (GRI) is another nonprofit, corporate sector-led program that provides a blueprint for companies looking for comprehensive guidance in disclosing the environmental impact of their operations. The GRI was founded in the United States in 1997 and the latest version of the GRI Sustainable Reporting Guidelines is called "G4," as it is the fourth version of the standards. The GRI develops via global working groups comprised of industry and technology experts, labor groups and the public at large. The disclosure scheme was originally geared toward providing information for investors if they have "green" investment portfolios or if they're concerned about a company incurring regulatory sanction. The GRI has forged partnerships with other private sector environmental management initiatives such as ISO, the Organisation for Economic Co-operation and Development, the United Nations Environmental Programme and the UN Global Compact.

Third, the Dow-Jones Sustainability Index (DJSI) emerged in 1999 to measure and provide a basis of comparison for the largest 2,500 listed companies on the Dow Jones Global Total Stock Market Index according to their CSR performance. The DJSI is updated annually

[39] The BCSD is affiliated with the World Business Council for Sustainable Development (WBCSD), a CEO-led initiative that emerged in 1992 after the Rio Earth Summit. Also, the BCSD has allied with several international NGOs such as Greenpeace, the Center for Research on Multinational Corporations and the Asia Sustainable and Responsible Investment Association.

[40] With the exception of Chung Hung Steel, each of these companies were contacted in the course of this research. Unfortunately, Feng Hsin and Tung Ho, with six EAF furnaces between them, choose not to participate in the survey.

and organized by region (World, Europe and Eurozone, North America and US, Asia Pacific) and country (Korea, Australia). Listed companies are monitored not only according to their environmental management scheme but also their corporate governance, labor practices, risk management strategies and more. Like ISO 14000 protocols, DJSI-listed firms must plan for continual improvement, and their disclosure of CSR data provides a reference point for investors and competitors.

Fourth, the UK-based Carbon Disclosure Project (CDP) promotes a standard and platform for disclosing corporate performance in GHG emissions and energy use data. Taiwan's BCSD recommends their approach, which was launched to address the shortcomings of another well-known GHG emissions reduction initiative, the nation-centric Kyoto Protocol. Working with 3,000 large-scale transnational businesses, their shareholders and supply chains, the CDP claims to have compiled the most extensive records on GHG emissions and energy use data in the world. Furthermore, the CDP has launched other programs targeting sustainable water use, sustainable local and national government operations, supply chain-focused SRI, green cities and deforestation issues.

Last, investor-driven governance networks (IGN) are theoretical initiatives that go a step further than the SRI opportunities mentioned above, denoting products (like "green" mutual funds) for investors who wish to support ethical companies. By purchasing these "social funds," stakeholders send a clear message to businesses that they care about corporate social and/or environmental performance. They might also participate to guard against corporate risk from current and future legislation or from future lawsuits, or to avoid the risk of a consumer backlash against high-impact industries. By the logic of IGNs, companies perceive that it's within their economic best interests to pursue social fund investment capital or to appease socially minded shareholders. This research was unable to find a link between an existing IGN product and Taiwan's EAF steel industry, but some scholars are critical[41] about the efficacy of this private

[41] Fleming and Jones (2013) dispute the efficacy of contemporary investor-driven governance networks from several angles. First, IGNs are a rare phenomenon. By and large, the investment atmosphere is geared toward traditional corporate values of short-term profit-maximization for shareholders. For most investors, like corporate managers, environmental practices are of secondary importance if they are considered at all. Moreover, average social fund investors also maintain conventional portfolios, with the bulk of their capital in more traditional networks. Second, existing IGNs have rarely exerted pressure on companies with any success. Although some large pension funds, the UK's Hermes and California's Public Employees' Retirement

sector governance initiative anyway.

2.4 Public sector factors

Taiwan has benefitted immensely from the international predecessors to its own environmental protection schemes. Many of the programs described below were modeled on similar initiatives started elsewhere that were later updated and tweaked to suit unique conditions on the island. Public sector influence on levels of environmental investment in EAF steel firms can be roughly analyzed according to regulations, resource sharing and incentive-based projects. These factors operate more on the periphery of EAF steelmaking than the technological, environmental and economic constraints detailed above. In other words, although its impact may be substantial, government pressure is not a part of the day-to-day realities of producing recycled steel for domestic and international markets.[42] Thus, with some historical and theoretical context, the explanation that follows describes public sector environmental governance in only as much detail as the issue of EMS development in the steel industry requires. This information was gathered primarily via personal interviews and through publications from TSIIA General Secretary (and former Industrial Development Bureau official) Jerry Huang as well as content from the Environmental Protection Administration's (EPA) English-language websites.

First, Taiwan's environmental regulation comes from a bureaucracy that functions on two main levels: the central government, and the county/municipal level.[43] The central government carries out the bulk of standard-setting, while their enforcement capabilities are delegated to regional centers of power.[44] The EPA, of course, is not the only government agency with

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System are two examples, have wielded their proxy-voting powers to influence corporate business practices, most social fund shareholders do not command a big enough market share to exert much influence. Third, to date most social funds accept the corporation's unsubstantiated reports of responsible behavior. Without subjecting these reports to a reliable external audit, their validity becomes questionable.

[42] As my interview subjects confirm, government regulation and regulatory monitoring in particular inform corporate decision making at key points in the facility design and maintenance process, but this influence is not felt so strongly at other times when economic concerns are paramount.

[43] In 1998, Taiwan nullified the political power of the provincial level to streamline government and enhance administrative effectiveness.

[44] These two levels of governance and administration don't always cooperate seamlessly. For instance, in a 2009 case involving dioxin contamination from steel furnace slag, the EPA

environment-related responsibilities. The Industrial Development Bureau under the Ministry of Economic Affairs (MOEA) has played an important role in building a sustainable future for Taiwan. In addition, the United States Environmental Directories Inc. have published online[45] a list of nine more government agencies charged with special environmental responsibilities and initiatives: the Aviation Safety Council, the Central Weather Bureau, the Council of Agriculture, the Council of Indigenous Peoples, the National Parks of Taiwan agency in the Ministry of the Interior, the Taiwan Forestry Research Institute, the Taiwan Water Corporation and the Water Resources Agency under the MOEA. Taiwan's environmental bureaucracy and programs, however, started developing well after the steel industry's rise to industrial fame and dominance in the 1970s.

Huang (2001) divides Taiwan's environmental policy development into three basic stages, each with special significance for Taiwan steel. First, in the initial development phase between 1974 and '79, the country witnessed the emergence of its first three cornerstone environmental laws: the Water Pollution Control Act (1974), the Solid Waste Disposal Act (1974) and the Air Pollution Control Act (1975). These laws, inspired by the Clean Air Act and other policies in the U.S., were initially written loosely and were accompanied by very relaxed enforcement efforts. Steel firms were not under tremendous pressure to comply at this time, however, they could easily forecast that stricter regulations were on the horizon, and those with the requisite capital and expertise started upgrading their facilities to prepare for these future demands. Things started to change in the 1980s with the next stage in environmental policymaking.

Huang marks the second stage in Taiwan's environmental protection efforts between 1980 and '89. The government tightened for the first time each of the cornerstone laws from the preceding period, the Solid Waste Disposal Act in 1980, the Air Pollution Act in 1982 and the Water Pollution Act in 1983. The revisions divided Taiwan into control zones with specialized criteria for environmental management; the Air Pollution Control Act, for example, divides Taiwan into three classes — national parks and protected areas, areas that meet air quality standards, and areas that do not meet standards — and enacts local policy and administrative

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allegedly said they needed to wait on the local environmental bureau before they could act. *See* Chao, V.Y. (2009). Lawmakers criticize EPA over duck scare. *Taipei Times* (Nov. 17, 2009).

[45] See earthdirectory.net/china#taiwan

measures accordingly. For instance, the Air Pollution Act sets emissions limits for several key environmental pollutants applicable to EAF facilities, including sulfur dioxide, particulate matter, and volatile compounds. Still, before the mid-1980s, most environmental laws and amendments arose in direct response to obvious and troublesome environmental issues. There was still no bureaucratic office expressly dedicated to these issues until 1986 with the inauguration of the Executive Yuan's Environmental Protection Task Force, which matured into the Environmental Protection Administration (EPA) the following year. This period also gave rise to the Noise Control Act (1983) and the Toxic Substance Management Act (formalized in 1986). Finally, this stage witnessed the increase in public sector environmental management manpower and enforcement, which subsequently led to some of the first industrial investments in pollution control equipment.

Huang's third and final stage marks Taiwan's emergence as an environmental standard bearer on par with leading industrialized nations. 1990 saw the adoption of the Environmental Impact Assessment (EIA) Law, which held that certain environmental standards must be met before new development could be undertaken, as well as a full-scale review and revision of all preceding environmental policies. By the mid-2000s, Taiwan's budget for environmental protection reached a high point in the hundreds of millions of New Taiwan dollars (Williams & Chang, 2008). This coincided with a rise in influential political parties identifying environmental protection efforts as a keystone in their electoral platform, as when former President Chen Shui-bian (2000-2008) and his Democratic Progressive Party vocalized their intent to refashion Taiwan into a "Green Island."

Generally speaking, Huang identifies two separate approaches to Taiwan's environmental governance in the public sector: preventive and administrative. Among the preventive measures are EIA policy and other approval protocols that predate industrial development — for instance, the air and water pollution prevention plans and the plan for waste clearing and disposal that firms must submit before an EIA inspection or audit clears them to break ground on a new facility or expand an existing one. Also, in the name of prevention firms must have someone on staff with specialized training in handling issues related to the air, water and toxic substances laws. Administrative laws, by contrast, are executed on a more regular basis and include measures such as in-house monitoring and reporting as well as random inspections conducted by operatives from the central or local governments.

Whereas failure to comply with a preventive law renders companies unable to legally develop their business, administrative transgressions can result in warnings, fines, or even a suspension of operations or an operational shutdown in especially egregious cases. These serious cases might also subject a firm to criminal prosecution, not to mention further loss of reputation and sanction from the public.

Taiwan's EPA is responsible for promulgating environmental regulations (and approving regulations devised by environmental protection bureaus at the regional level). In the past decade the EPA has put forth some key standards specifically related to steel production with electric arc furnaces. For instance, the Steel Smelting Industry Electric Arc Furnace Particulate Pollution Control and Emission Standards (煉鋼業電爐粒狀污染物排放標準) first came on the scene in 1993 and complements the broader Air Quality Standards (revised May 14, 2012) in setting forth limits and control strategies for particulate matter (PM2.5) from steel production off-gases. According to the latest English press releases available on the EPA website in December 2014, the agency is also conducting research to make existing emissions limits more strict, based in part on the rapidly developing pollution control technologies coming on the market. Like other industrial regulations, the latest particulate standards are to be implemented in two stages to encourage firms to gradually transition. All EAF facilities are expected to decrease their particulate emissions from 50 mg/Nm_3 to at most 30 mg/Nm_3 in the first stage before decreasing to 15 mg/Nm_3 in the final stage by Jan. 1, 2017.

The EAF particulate control standards are more ambitious than just emissions limits; they also cover production guidelines and protocols for in-house environmental impact monitoring. For example, these regulations are undergoing further revisions to stipulate that furnace lids must remain closed and cannot be removed during the melting process, except to add raw materials or extract the molten steel (two procedures that take less than six minutes each). In addition, the EPA is considering standardizing a more rigorous method of taking pollution samples based on the U.S. EPA's Method 5D protocols.

The EPA has also announced that it is weighing the possibility of standardizing dust extractor systems for EAF facilities in revisions to the Iron and Steel Basic Industry Dust and Ash Storage Extension Application Review Working Guidelines (鋼鐵基本工業集塵灰貯存延長申請

審查作業要點). These laws were last revised on June 30, 2009;[46] whereas the previous guidelines focused on best available techniques for storing the waste prior to treatment, the revised guidelines also call for annual waste treatment targets. The EPA's website states that, owing to the limited capacity of landfills, "recycling should be the first priority for this dust and ash,"[47] and the department has strengthened its inspection protocols and GPS tracking systems to prevent illegal dumping. Furthermore, they have taken (unspecified) steps to increase the efficiency of recycling and treatment "organizations" to facilitate more responsible waste disposal.

Since the EPA came forth with data pointing to Taiwan's steel smelting facilities as the country's main source of dioxins,[48] both central and local government agencies have tackled the issue with emissions standards. The EPA came out with their policy solution in June 2004: the Steel Industry Smelting Plant Dioxin Controls and Emissions Standards (鋼鐵業燒結工場戴奧辛管制及排放標準). Kaohsiung City, which houses the highest concentration of EAF facilities in the country, also drafted a new policy to complement emissions limits set by the central government while addressing the unique conditions of the region; the Kaohsiung City Steel Smelting Plant Dioxin Controls and Emissions Standards in accordance with the Air Pollution Control Act were ratified by the EPA on Aug. 14, 2008 and went into effect in 2010. In addition to setting forth strict regulations for future steel smelting facilities, these standards also apply to existing facilities.

Some regulations are based not on laws formulated in other nations like the United States but on international agreements. Because of Taiwan's sensitive diplomatic status, the country is generally unable to participate in international environmental treaties. Still, in large part to build its soft power and to ease its ability to integrate into global production cycles, Taiwan has made efforts to follow the spirit of international treaties without being a formal party to them. A few of these efforts are documented online at English-language websites such as the "Towards

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[46] This revision was likely in response to the findings of the EPA's southern region inspection squad, which in March 2009 revealed to the public its discovery of 40 cases — some involving steel production facilities, some involving aluminum — in which EAF dust was not disposed of in accordance with existing regulations. *See* Lu, M. (2009). Firms ignoring dust regulations. *Taipei Times* (March 17, 2009)

[47] See http://oldweb.epa.gov.tw/en/NewsContent.aspx?NewsID=1377

[48] See http://oldweb.epa.gov.tw/en/NewsContent.aspx?NewsID=816

UNFCCC" (The United Nations Framework Convention on Climate Change) site,[49] which emphasizes that "Taiwan is willing to contribute (to the) global community." For instance, the same EPA-sponsored English-language website states that Taiwan has endeavored to control and reduce POP emissions in line with the Stockholm Convention, and the country's dioxin emissions had decreased 78% in 2008 since POP controls came into effect in 1997. Taiwan has also controlled ozone-depleting substances in accordance with the Montreal Protocol since 1994, and it ratified the Waste Import and Export Management and Basel Convention Implementation Plan in 2000, despite not being full-fledged participants in these treaties.

The Executive Yuan-established National Council for Sustainable Development (NCSD) was a bureaucratic outgrowth of the Agenda21 agreement and the Rio Declaration put forward at the 1992 United Nations Earth Summit in Rio de Janeiro, Brazil. It was upgraded to legal council status in November 2002. Adopting the ethos of "Think Global, Act Local," the NCSD organizes working groups (for instance, the Green Economy Task Force convened in Sept. 2012) to bring together experts from a variety of departments in the public sector along with academics and civil organization representatives. These groups tackle Taiwan's sustainability issues via policymaking efforts and by crafting annual reports and promoting guidelines such as the "Action Plan for Sustainable Development" (2002) and the annual "Taiwan Sustainable Development Indicators." "Taiwan Agenda 21" (2004), for example, supports the continued restructuring of Taiwan's economy away from heavy industries like steel, cement and petrochemicals production and "toward a high knowledge- and technology-intensive service-based modern knowledge economy." The NCSD also presents the Taiwan Sustainable Development Awards on a yearly basis.[50]

The R.O.C. Annual Enterprise Environmental Protection Awards have been part of the public sector's incentive-based initiatives since 1992. China Steel has been a prominent recipient in the past among the 10-20 other enterprises selected for recognition each year. Under the awards scheme, enterprises undergo evaluations based on their records of environmental protection planning and management, their achievements in environmental protection, and their promotion of environmental protection to the public. In 2014, no enterprises earned an award in the category for small- and medium-sized enterprises.

[49] See http://unfccc.epa.gov.tw/unfccc/english/index.html
[50] This and more information about NCSD is available on their website, www.ncsds.org.

Participation in a European emissions trading system (ETS) is another prominent incentive-based public sector initiative. Like the awards, this initiative has to develop further to fully penetrate industrial SMEs. Briefly, ETS, known as cap and trade in the United States, works by creating a system of credits based on corporate GHG emissions levels and allows enterprises to trade these credits for their market value — i.e., based on whether they need to buy credits to offset high emissions or whether they can sell credits based on their success at GHG reduction. For ETS to work, a variety of systems must work cooperatively, including emissions standards (the "cap" in cap and trade), reporting protocols, a registry system and a trading platform. EPA documents also stress the importance of a legal foundation for ETS that incorporates the Energy Management Act (2009) and the Renewable Energy Development Act (2009), the Greenhouse Gas Reduction Bill (introduced to the Legislative Yuan in 2006, revised in 2008 and still awaiting approval) and the Energy Tax Bill (also pending). In lieu of these bills making it through the Legislature, the government took executive action to establish a third-party verification system in 2009 and an emission credit system in 2010. There has also been progress in linking Taiwan's ETS to international cap and trade programs in Europe. Still, there's a long way to go before ETS makes an indelible mark on Taiwan and EAF firms in particular.

Moving on to public sector initiatives based on resource sharing, Corbett and Kirsch (2000) focus on financial subsidies for enterprises seeking ISO 14000 certification. In 2000, the Industrial Development Bureau contributed 40-60% of ISO 14000 preparation costs annually to as many as 50 SMEs engaging in "demonstration projects" that might result in innovation worth sharing domestically. Generally speaking though, EAF firms are most likely to benefit from government subsidies only indirectly, when these funds are funneled into research and development (R&D).

By the early 2000s, the government's R&D budget was subsidizing about a quarter of all expenditures on industrial technology innovation nationwide (Hsu and Chang, 2001). This infusion came mostly via the Ministry of Economic Affairs, which evaluates domestic industry and strives to enhance its competitiveness. Before 1996, the bulk of R&D initiatives took place in non-profit research institutes such as the acclaimed Industrial Technology Research Institute. Since that time, competent members of the private sector have picked up the slack (e.g., the private sector initiates outlined in the previous section) and the role of government expertise has

shrunk to a more supportive role.[51] Still, the key resource that the government shares to boost environmental protection is not money but information. The environmental protection awards are one example of these efforts that aim to proliferate environment-oriented R&D. The NCSD Annual Report for 2010 mentions the efforts of the Industrial Development Bureau (under MOEA) in conducting GHG inventories of 380 energy-intensive manufacturers (in the fields of steel, petrochemicals, paper, synthetic fibers and cotton printing and dying) and providing guidance on reducing firms' carbon footprint. The EPA also coordinates training for required corporate environmental specialists as needed and, of course, maintains an accessible online database of environmental law and news.

Finally, the significance of environmental progress in the public electoral processes is worthy of mention. Particularly at the local level and in regions afflicted by environmental damage (see Figure 14), candidates commonly seek (re-)election on platforms that include a strong stance toward environmental health and regulation. Indeed, independent parties at the grassroots level sometimes organize to challenge seemingly industry-centric parties in the mainstream (as in Green Party Taiwan) or even to counter specific and localized environmental destruction (as in the Trees Party, which splintered from Green Party Taiwan in 2014). Still, the mainstream DPP and KMT parties have a record of addressing environmental issues in policy and rhetoric, with the progressive party enjoying a distinct edge in this regard.

In sum, the public sector has various tools at its disposal to coerce and encourage EAF steel companies to increase their investment in environmental solutions. These tools can be roughly categorized as resource sharing (in the form of research and development subsidies) and information sharing; incentive programs like environmental awards and ETS; and regulations. Environmental regulations put forth at both the central and local government levels are the primary means for impacting industrial EMS, and the efficacy of these measures depends on administrative protocols like in-house reports on environmental monitoring and especially periodic inspections conducted on behalf of the government. The above summary also highlights certain limitations to public sector policymaking and praxis such as the potential for polluting facilities in less concentrated industrial areas to evade the pressures of control zone-based

[51] On Nov. 16, 2011, however, National Taiwan University opened a steel research center on campus dedicated to developing advanced steel technologies. *See* Anonymous. (2011). NTU opens center to create advances in steel technology. *Taipei Times* (Nov. 17, 2011).

initiatives. Other limitations include the possibility that new laws will affect future but not existing facilities, potential regulatory loopholes arising from reliance on firm-generated data and irregular inspections, and the lengthy delay between drafting local standards and applying them after EPA approval. Furthermore, the fact that Taiwan's policies tend to get drafted in response to policymaking[52] and technological innovation[53] happening elsewhere suggests that the island could do more to proactively strengthen standards for EMS instead of just playing follow the leader.

2.5 Voluntary sector factors

According to Huang and Kung (2010), modern-day companies are experiencing intensifying pressure from environmental governance mechanisms to adopt a CSR approach (CSR is discussed in greater depth in the literature review). In their research into environmental disclosure patterns in Taiwan, they also assert that non-shareholder stakeholders are increasingly influential in the corporate decision-making process. Be that as it may, my research uncovered relatively little evidence of direct voluntary sector involvement in environmental issues emanating specifically from EAF steel production. This is most likely because the distinction between EAF and other types of steel production is highly technical and outside the sphere of common knowledge. Also, EAF facilities are typically small- and medium-sized enterprises that are relatively few in number. According to TSIIA, Taiwan is home to a total of 21 electric arc furnace facilities, many of which are set apart from residential areas in industrial zones where more than one type of factory operates. This allows companies to effectively diffuse their environmental impact, in the mind of the public, to industrial zones as a whole.

Still, the following paragraphs describe some pertinent environmental incidents involving steel companies (including EAF firms and their affiliated waste treatment facilities). These incidents mainly revolve around the unsafe disposal of furnace slag and EAF dust containing dioxins, chromium, and high concentrations of heavy metals. Also, the tactics and ideology of

[52] Besides the aforementioned policies, Taiwan's hazardous waste laws are similar to the Resource Conservation and Recovery Act (RCRA) in the U.S., and Taiwan's Soil and Groundwater Reclamation Law is based on the U.S.' RCRA and Comprehensive Environmental Response, Compensation and Liability Act (Huang, 2001).

[53] Stories of Taiwan's use of foreign technology, however, don't always have a happy ending. Huang (2001) describes a German company that was hired to process the island's EAF dust. Their equipment clogged and broke down.

voluntary sector actors to exert pressure on polluters directly, and indirectly via pressuring the government, is explored. In sum, these agents typically employ petitions, press conferences, protest marches, lawsuits, environmental testing and coalitions with lawmakers and political parties to influence those in power.

The spatial dynamic of industrial zones/concentrated industry is a sticking point, especially in Southern Taiwan. In a June 2014 rally against development plans in Kaohsiung, one resident activist said the following: "If the project is approved, we will become like the filling in a sandwich biscuit, squeezed in a small area between several industrial areas, including state-run refiner CPC Taiwan, state-owned (sic) integrated steelmaker China Steel, and state-owned Taiwan Power." The same protester stated that many local residents had succumbed to sickness from air pollution.[54] In another case, hundreds marched in protest of the construction of a galvanizing[55] factory at Quintain Steel's facilities in Guantian (官田) District, Tainan. Instead of problems arising from the over-concentration of industrial activity as in Kaohsiung, activists decried the placement of the factory on land adjacent to residential areas in an agricultural district, fearing the pollution of local farmlands and fish ponds.[56] Wei Chih Steel Industrial Co., an EAF facility contacted for this study, is also located in Guantian District and features a photograph of its facilities behind what appears to be agricultural land on the homepage of its website.[57] Indeed, the public tends to direct its frustration toward industrial developments[58] or industrialization in general, or companies that have been caught mishandling their environmental obligations in particular. A 2005 case involving Taiwan Steel Union Co., an organization that treats hazardous EAF furnace dust, exemplifies the latter.

In a report published by the EPA on Dec. 17, 2005, Taiwan Steel Union Co. was identified as the most likely culprit behind high levels of dioxins found in duck eggs in Changhua County,

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54 Lee, I.C. (2013). Kaohsiung residents rally against development plans. *Taipei Times* (June 4, 2013)

55 A galvanizing facility entails extensive use of chromium.

56 Anonymous. (2011). Hundreds protest against new steel plant in Tainan. *Taipei Times* (July 4, 2011)

57 *See* www.weichih.com.tw.

58 Taiwan's nuclear power industry and its Fourth Nuclear Power Plant has been a prime target for public rebuke in recent years, and even energy-generating windmills have been subject to intense scrutiny by neighbors who cite health concerns and negative effects on local bird populations.

Hsienhsi (線西) and Shenkang (伸港) Townships.[59] One Shenkang farm in particular owned by duck farmer Huang Chi-wen (黃奇文) and located adjacent to Taiwan Steel Union's property tested positive for excessive levels of dioxin throughout the premises, including the soil, plants and animal feed.[60] The dioxin profile from Huang's farm even matched that of Taiwan Steel Union Co. effluent, further confirming their guilt in emitting dioxins far in excess of the legal limit.[61] Huang and five other farms in the county were forced to cease production, cull 28,000 egg-laying ducks, and live on NT$15,000 government subsidies for a time or until their products could be declared safe. As is typical in these cases, the victims of egregious lapses in corporate environmental management are welcome to sue the company that threatened or extinguished their livelihood and/or health.

In Huang's case, the director-general of the Department of Air Quality Protection and Noise Control said the government would help him with a lawsuit if he desired. Besides government support though, some of Taiwan's most active and visible nongovernmental organizations (NGOs) help individuals and community self-help groups carry out lawsuits as their primary function.[62] In fact, it's safe to say that in lieu of more widespread environmental activism targeting EAF steel firms, the threat of lawsuits is a particularly potent form of pressure for EMS development emanating from the voluntary sector.

In addition, some voluntary sector actors affect steel industry players indirectly via lobbying the government. In 2012, for instance, the Citizens of the Earth Foundation (地球公民基金會) collected over 12,000 signatures and city council backing for a petition in support of stricter

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[59] Chou, J. (2005). Steel factory suspected of causing high dioxin levels. *Taipei Times* (Dec. 17, 2005)

[60] Another case of ducks contaminated with dioxins (and heavy metals like copper, nickel, chromium, zinc, arsenic and lead) came to light in 2009. These animals had been raised on farmland covering an old industrial landfill containing steel furnace slag in Daliao (大寮) Township, Kaohsiung. All 9,000 birds were culled. *See* Author unknown. (2009). Toxic ducks spark health scare. *Taipei Times* (Nov. 13, 2009).

[61] Taiwan Steel Union Co. also made the news in 2014, when environmentalists protested against their plan to expand their EAF dust treatment plant, fearing intensified environmental consequences for the facility's neighbors. *See* Lee, I.C. (2014). Taiwan Steel Union's ash treatment plan draws fire. *Taipei Times* (May 30, 2014).

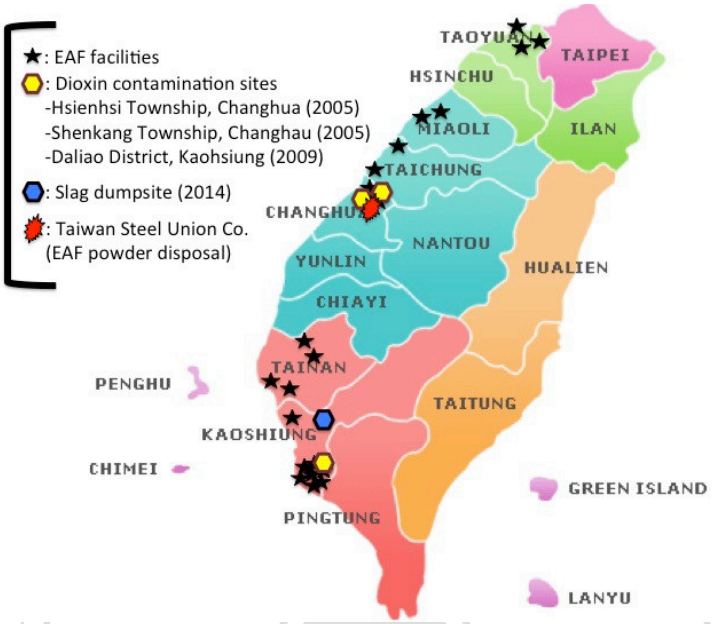
[62] Wild at Heart and the Environmental Jurists Association are two such organizations that contributed to this study.

pollution emissions standards for Kaohsiung City.[63] Press conferences are also a staple in Taiwan's voluntary sector toolkit. Press conferences spread the word about environmental issues, particularly by attracting the media, as in 2013 when academics at the Taiwan Academy of Ecology pressured the Forestry Bureau to investigate Dragon Steel's "green forestry" efforts. Dragon Steel, an EAF operator and subsidiary of China Steel, had allegedly used herbicide to clear out indigenous species and plant high-value trees in defiance of the spirit of the government's sustainable forestry initiative.[64]

In a recent case from May 2014, residents from Kaohsiung's Cishan (旗山) District, Citizens of the Earth activists and a legislator called attention to China Steel's alleged dumping of furnace slag onto farmlands, contaminating a source of municipal water. Representatives of community self-help associations filed formal petitions with the Water Resources Agency, the EPA, and the Council of Agriculture, later telling media that these agencies denied any wrongdoing and refused to act. A Cishan Respect and Caring Education Foundation representative also claimed that the local Environmental Protection Bureau classifies furnace slag as an industrial "product" rather than industrial waste and it thus eludes proper monitoring by the public sector.[65] The Chinese-language Taiwan Environmental Information Center online[66] clarifies that, whereas EAF dust is considered a hazardous industrial waste, furnace slag is not considered hazardous (but it is still a waste product). Furnace slag disposal was first regulated in 2008; beforehand there were no strict laws governing its management. Figure 14 shows a regional map featuring EAF facility locations, the home of Taiwan Steel Union Co. and sites of environmental destruction attributed to the steel industry.

[63] Fang, C.H. & Pan, J. (2013). Kaohsiung takes action on air pollution. *Taipei Times* (April 4, 2013)
[64] Lee, I.C. (2013). Bureau to probe forestry claims. *Taipei Times* (May 23, 2013)
[65] Lee, I.C. (2014). Furnace slag is dumped in farmland at Cishan. *Taipei Times* (May 28, 2014)
[66] *See* e-info.org.tw/node/49455.

Figure 14: EAF industry and related environmental damage sites



The Cishan District case epitomizes key themes in voluntary sector criticism of business-as-usual practices: industry will cut any corners they can in the pursuit of profits, and environmental protection agencies too often aid and abet this behavior. The EPA and its affiliated agencies are especially the object of scrutiny, as any perceived failure to carry out their responsibility (or worse, a perceived lack of interest in doing so) contradicts their *raison d'être*. Environmental groups generate bureaucratic momentum to carry out administrative duties when they attract media attention to an issue. Also, when experts from the voluntary sector conduct tests on slag-contaminated water (as they did in Cishan), this action in essence supplements the sometimes stretched administrative capacity of public sector environmental agencies.

Expert critiques of existing environmental policy might also have profound indirect consequences for environmental investment levels when public sector advocates help change the laws. The results of the 2014 Nine-in-One Elections — in which the DPP secured crushing landslide victories against the ruling KMT party throughout the island — has particularly piqued the interest of environmentalists who see the potential for change in the unsettling of KMT power. Time will tell if this optimism in the opposition party was deserved.

Finally, the fact that other hot-button issues tend to divert the attention of voluntary sector actors away from EAF steel production does not mean these actors have a minimal part in corporate environmental decision making. In fact, research from industrialized countries in particular suggest that the general cultural and political climate in which factories operate can

effect operations through a variety of means, from social norms disseminating through a corporate hierarchy to increasingly powerful NGO lobbies. These factors and more will be explored in the literature review section.

3. Review of Literature

The preceding background chapters tackle the important context for the independent variables (environmental initiatives in the private, public and voluntary sectors) as well as the dependent variable (EMS development in EAF facilities) in this study. The literature review segment that follows delves into prevailing theories about the connection between these two kinds of variables, particularly what kind of mechanism utilizes multi-sector pressures and transforms them into environmental investment levels through corporate decision making. Much of the existing literature does not attempt to discover what is essentially proprietary information about a firm (the technologies and levels of investment reserved for environmental protection efforts); many studies instead choose environmental disclosure as a barometer of a corporation's commitment to environmental protection.

Corporate environmental disclosure is a complementary phenomenon to corporate environmental investment. Both are examples of CSR behavior, although investment more directly leads to positive environmental outcomes. Most of the corporate environmental disclosure literature revolves around two complementary theories: legitimacy theory (Tilling, 2004; Palazzo & Scherer, 2006) and stakeholder theory (Freeman, 1984; Mitchell et al., 1997; Key, 1999; Parmar et al., 2010). Legitimacy theory predicts that organizations will change their environment-related behaviors when an incident occurs that threatens their acceptance among critical stakeholders. This acceptance is not just abstract or psychological. Stakeholders command resources that are vital for a corporation's success. These resources include taxes and contracts from the public sector, patronage from consumers, and investment from the financial sector. The flow of these resources toward or away from a company's best interests signifies that company's legitimacy and describes its exposure to networks of pressure under stakeholder theory. The following paragraphs outline standout theories regarding corporate social responsibility and corporate citizenship in general before giving an in-depth breakdown of the legitimacy/stakeholder theory of firm behavior.

3.1 Corporate social responsibility (CSR)

The definition of CSR is not consistent throughout the literature. Moir (2001) describes how early definitions focused on a corporations' perceived obligation to society and later shifted to stress their responsiveness to societal mores and pressures. Wood (1991) integrates these trends to conceptualize a CSR that stems from a firm's understanding of its connection to and impact on society and becomes manifest in the espoused principles and initiatives that emerge from this understanding. McWilliams and Siegel (2001: 117) set forth a more demanding interpretation, defining CSR as "actions that appear to further some social good, beyond the interests of the firm and that which is required by law." For example, CSR must transcend mere compliance with existing environmental regulations; instead corporate assets must target goals beyond the profit motive. By contrast, much of the recent literature emphasizes how CSR complements the profit-maximizing mentality and becomes a form of competitive advantage (Garriga & Mele, 2004; Jamali & Mirshak, 2007; Babiak & Trendafilova, 2010) and a shortcut to establishing a firm's reliability and enhancing the perceived quality of its goods and services.[67] This study uses the World Business Council for Sustainable Development's definition of CSR (cited in Moir, 2001: 18), with a focus on environmental and health-related issues:

> "CSR is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large."

Although the present research stresses EMS development (investment in environmental technology and more sustainable manufacturing protocols) as the primary example of CSR in action, the literature contains a much wider array of activities that exemplify corporate social responsibility. These activities — from a variety of industries — include adopting more inclusive human resources practices, halting animal testing, recycling, supporting the local economy, manufacturing products that promote positive social attributes, hosting educational and cultural events, etc. (McWilliams & Siegel, 2001). Sometimes corporations partner with groups in the private, public or voluntary sectors to scale-up their CSR initiatives, gain wider exposure, and benefit from the experience and expertise of their progressive co-collaborators (Jamali & Mirshak, 2007). The China Steel website declares its commitment to environment-oriented CSR

[67] In a similar vein, CSR might become a corporate strategy for attracting and retaining employee loyalty or preventing union action in certain countries.

via environmental disclosure (self-reporting of environmental impact) and environmental initiatives that ultimately impact public health issues. CSR efforts also encompass advertising and public relations work to publicize these initiatives and benefit from an enhanced reputation (McWilliams & Siegel, 2001; Garriga & Mele, 2004), and an important duty for executives may be to scan the local and industrial environment for CSR-related information to determine hot trends that help firms plan for the future (Jamali & Mirshak, 2007). Particularly in large corporations, an entire department might be devoted to CSR.

While cutting edge CSR programs involve more and more comprehensive systems of ethical management and production, some executives — particularly in developing countries — are more prone to consider occasional philanthropic work the sum total of their responsibility to society (Jamali & Mirshak, 2007). This is often the case because of traditional attitudes about the dichotomy between the private and public sectors — the former cares only about making money while the latter attends to societal needs — and the perception that the economic consequences of CSR are either neutral or negative for firm profitability. Table 3 shows important categories of CSR initiatives and emphasizes the costs of progressive action. Even for businesses that see more comprehensive CSR programs as a competitive advantage, the potentially high cost of CSR explains why corporations implement it strategically and according to a cost-benefit analysis (McWilliams & Siegel, 2001).

Table 3: Resources/inputs used in provision of CSR

Resource or Input	CSR-Related Resource or Input	Additional Resource or Input Costs
Capital	Special equipment, machinery, and real estate devoted to CSR	Higher capital expenditures
Materials and services	Purchase of inputs from suppliers who are socially responsible	Higher-cost materials and services (intermediate goods)
Labor	Progressive human resource management practices and staff to implement CSR policies	Higher wages and benefits and additional workers to enhance social performance

Source: McWilliams & Siegel, 2001

Importantly, the majority of literature on CSR has its basis in normative theories of the firm; in other words, the concept emerged to idealistically suggest a system of business ethics (how firms *should* act) rather than to capture the true inner workings of the economic sphere. However, numerous scholars have also explored the descriptive powers of the CSR concept — to

describe or explain firm operations and decision making — as well as its instrumental value[68] in attempting to predict the outcomes of CSR programs on firm growth and profitability (Donaldson & Preston, 1995). Similarly, Garriga and Mele (2004) classify CSR thoughts into instrumental, political and integrative[69] as well as ethical theories.

One of the earliest theories about CSR is Milton Friedman's agency theory.[70] According to agency theory, firm managers are obliged to act as agents on behalf of their shareholder clients. "Shareholder value maximization" defines the purpose of all corporate strategy in this paradigm (Garriga & Mele, 2004). By contrast, agency theorists presume that when managers adopt CSR, they do so as agents of their personal, social, and political enrichment — often at the expense of shareholders. Friedman, of course, believed that firms should focus solely on increasing shareholder returns. This idea began to lose traction in much of the academic literature by the 1980s, which saw the rise of Corporate Social Performance literature (Preston, 1978; Carroll, 1979; Wood, 1991), and Freeman's seminal work on stakeholder theory (Freeman, 1984).

Although stakeholder theory is widely considered the dominant approach to understanding CSR (along with the implied legitimacy concept), other theories have also tried to move CSR away from its normative roots to serve as a more descriptive idea for understanding corporate behavior. For instance, Jones (1980) conceptualizes CSR not as a system of principles or actions but rather as a process of decision making that champions social targets as well as economic ones. Similarly, McWilliams and Siegel (2001) use a "supply and demand" model that accounts for a wide range of variables[71] to explain corporate decision making on CSR as the result of a cost-benefit analysis.[72] Schwartz and Carroll (2003) assert that CSR operates in ethical (accepted moral standards), legal (regulatory compliance), and economic (centered on profit motive) dimensions that give rise to seven possible types of corporate action (see Figure 5). This theory also helps categorize firms by the ethos that guides their overall operations — i.e., a business that

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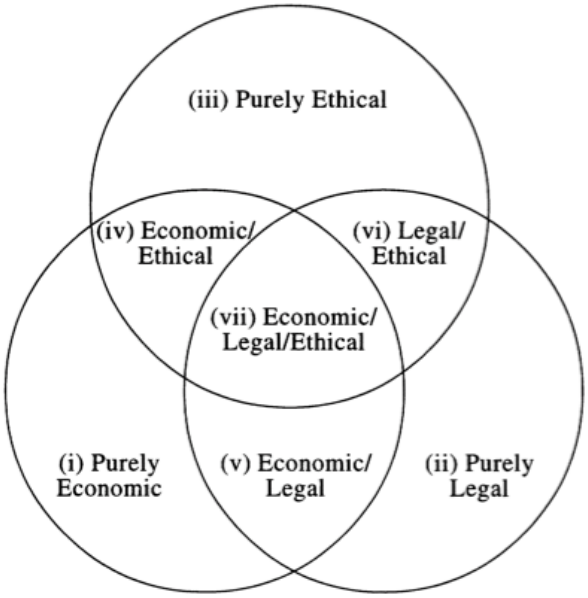
[68] Donaldson and Preston (1995) assert that corporate giving is almost always instrumental.
[69] Integrative theories assert that corporations are embedded in and reliant on their societal foundations.
[70] As published in his seminal *New York Times* article in 1970, "The social responsibility of business is to increase its profits."
[71] These variables include a company's size, level of diversification, research and development, advertising, government sales, consumer income, labor market conditions, and stage in the industry life cycle.
[72] They conceptualize CSR as a form of investment, particularly to enhance a firm's competitive advantage in a high-growth industry (Russo & Fouts, 1997; Garriga & Mele, 2004).

pays more or less equal attention to ethical, economic and legal concerns over time is said to have a *balanced* orientation to CSR.

Figure 15: Schwartz and Carroll's three-domain model of CSR



Source: Schwartz and Carroll, 2003

The latest developments in descriptive CSR theory also highlight how the concept might require different thinking in different contexts. Perrini (2006) recommends that only large firms be analyzed from the theoretical perspective of stakeholder theory, while research on SMEs and CSR should take a "social capital" approach. Matten and Moon (2008) describe how CSR manifests differently in distinct cultural paradigms, from the "explicit" promotion of initiatives to enhance corporate legitimacy (as in the American context) to the culturally embedded "implicit" progressive values and expectations for corporate behavior that exist in Western Europe and Scandinavia. Taiwan, for instance, also falls into the category of "implicit" CSR when it comes to employee health care; firms typically do not emphasize this aspect of the social good they create (as is the case in the US) because they work in concert with a national health care system that handles most of the burden for them.

Research on CSR began with a focus on the ethics and broad societal effects of the phenomenon and shifted toward performance-orientated managerial research (Garriga & Mele, 2004; Lee, 2008). Much of the research on CSR since the 1990s has endeavored to find a link between CSR activities and financial performance. In Margolis and Walsh's (2001) book-length literature review of research published 1972-2000, of the total of 95 empirical studies conducted,

53% established a positive relationship between CSR and financial performance, 24% found no relationship, 5% found a negative relationship, and 19% of studies had mixed results. Recently, the 2013 winner of the Moskowitz Prize for quantitative research into socially responsible investing (sponsored by the University of California at Berkeley's Haas School of Business) went to Caroline Flammer for her paper[73] asserting that CSR activities (including environmental protection efforts) enhance shareholder value and long-term operating performance. Besides quantitative analyses, especially since the early 2000s, more research has used content analysis to measure volume and unpack the content of social and environmental disclosures in corporate annual reports, public relations and advertising materials (Belal, 2001). Also in the early 2000s, more studies began to explore CSR in the special context of developing countries (Belal, 2001; Barkemeyer, 2007; Jamali & Mirshak, 2007; Ramasamy, 2007). These theories are coming of age alongside a newer paradigm for business ethics, one that pays special attention to economic and political changes at the national and global levels: corporate citizenship.

3.2 Corporate citizenship (CC)

Corporate citizenship emerged in the 1980s out of the struggles of the welfare state and globalization, both harbingers of the multinational corporation, falling prices, technological development, and deregulation. In this new era, corporations wield power comparable to nation-states, and the idea of corporate citizenship attempts to outline the new global societal role of the firm in light of this ascent. Along these lines, 34 of the world's largest multinational corporations signed a joint statement at the World Economic Forum in January 2002 called "Global Corporate Citizenship: The leadership challenge for CEOs and boards" to acknowledge their duty to wield power responsibly. Institutions have also sprung up dedicated to exploring and promoting CC ideas, including the *Journal of Corporate Citizenship*, research centers at Boston College (US), Warwick University (UK), Deakin University (Australia), and Eichstatt University (Germany), as well as new departments in governments, consultancies and think tanks worldwide (Matten &

[73] Flammer, C. (2013). Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. *University of Western Ontario Working Paper*

Crane, 2005).[74] In short, these institutions promote the idea that businesses can only perform well economically by contributing toward a stable social, environmental and political atmosphere.

The differences between CC and CSR are subtle; some scholars even use the two terms interchangeably (Matten & Crane, 2005). The principle distinction seems to lie in the more comprehensive, globalized and modern worldview put forth by corporate citizenship. Whereas corporate social responsibility emphasizes the ethical principles that govern how business responds to feedback from its surroundings, corporate citizenship goes farther to conceptualize business as a subject and beneficiary of an integrated society — with demands and responsibilities placed on it similar to those shouldered by other powerful members of the citizenry. CC evokes the beneficial potential of the same mentality that brought about the problematic *Citizens United* case in the US (which declared that a corporation was a legal person and therefore able to freely make financial contributions to political campaigns) as well as the Information Age phenomenon that has brands interacting with the public through social media platforms (e.g., Twitter, Facebook) as if they were people.

The actions associated with CC are similar to those associated with CSR. The concept emerged in the corporate and academic discourse meaning little more than philanthropic donations handled strategically, i.e., furthering the company's profitability by building "social/reputational capital" (Matten & Crane, 2005; Gardberg & Fombrun, 2006). Considering the term's special salience for multinational corporations, CC also stresses a kind of reversal of focus from the global to the local, with corporations "giving back" to their respective communities. Importantly, CC also involves initiatives that some businesses take to effectively supplant the traditional paternalistic role of government[75] in caring for the citizenry: pension funds linked to international capital markets, industry-level self-regulation, ensuring a living wage for employees, and building schools, medical centers and roads, as well as participation in national political organizations and transnational organizations like the European Union, World Bank, the International Monetary Fund, and the United Nations (Matten & Crane, 2005).

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[74] Interestingly, Matten and Crane (2005) also state that, whereas CSR discourse has been adopted most fervently in academia, primarily corporate actors have nurtured the discourse about CC.

[75] This approach is particularly fitting considering the global shrinking of the welfare state and trend toward neoliberal governance and the resulting cuts in social programming.

The theoretical basis of CC has a similar normative flavor as that of CSR and largely takes an ethical perspective on the rights, responsibilities and partnerships of businesses. The concept particularly owes a lot to social contract theory, rather than stakeholder theory as in CSR (Garriga & Mele, 2004), which further stresses the integration of businesses within society at large as opposed to theories that take organizations themselves as the primary level of analysis. Much like CSR, however, corporate citizenship has been interpreted and used differently by various scholars. Matten and Crane (2005) identify two main strains of CC theory: one that describes CC as strategic philanthropy and another that equates CC with CSR. In response, they map out a more precise theory that unpacks "citizenship" into the administration of social, civil and political rights conventionally ensured by governments. Thus, corporations are not considered citizens themselves but rather the gatekeepers for real citizens to exercise their rights. By contrast, Moon et al. (2005) suggest that corporations might qualify as citizens based on their participation in civic processes, and Carroll (1998) classifies corporations as citizens based on four responsibilities they share with private citizens: the responsibility to be profitable, to obey the law, to engage in ethical behavior, and to give back through philanthropy.

3.3 Legitimacy Theory

Corporate social responsibility and corporate citizenship theory both help to define this study's place in the existing literature, but a greater emphasis on descriptive approaches within these theories gives us a better idea of the mechanism that governs the relationship between multi-sector initiatives and EMS development in Taiwan's EAF steel industry. First, legitimacy theory explores the self-interested motivation for businesses to respond to societal pressures. The theory has been a popular explanation for corporate environmental disclosures since the early 1980s (O'Donovan, 2002) and has been a mainstay in accounting research throughout the 1990s and early 2000s. According to Suchman (1995: 574), "legitimacy is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions." In other words, businesses gain legitimacy when a society perceives that their actions are in alignment with the dominant moral expectations of the time. From the perspective of the firm, ensuring legitimacy becomes a context-based scheme of image management (Branco & Rodriguez, 2006). Thus, in particular regions or during historic periods where environmental values have not been adopted, heavily

polluting businesses can operate with their social legitimacy intact.

Suchman (1995) breaks legitimacy theory down into two separate classes: institutional legitimacy and organizational legitimacy. The broader macro-theory of legitimacy, institutional legitimacy theory, describes how organizational structures (capitalism, government, religion) gain wide acceptance from society. On this level of analysis, legitimacy more or less equals institutionalization, and legitimized systems seem "natural" and "meaningful" (Suchman, 1995: 576). Both the macro-level and organizational theory of legitimacy involve special consideration for so-called crises of legitimacy, in which an incident occurs that severely dampens an institution or firm's reputation in a community, thereby diminishing its command of valuable resources. This study and the majority of research on CSR looks at legitimacy on an organizational level (with the business as the central unit of analysis instead of society at large), which in the literature involves a variety of concepts stemming from social contract theory in political science to resource dependence theory, new institutionalism, and management theory (Barkemeyer, 2007).

The root of organizational legitimacy theory is "a process, legitimation, by which an organization seeks approval (or avoidance of sanction) from groups in society" (Kaplan, 1991: 370) in order to obtain resources (Suchman, 1995) and prevent losses. Other studies (Branco & Rodriguez, 2006) repackage the search for approval as a kind of pursuit of congruence:

> "Organizations seek to establish congruence between the social values associated with or implied by their activities and the norms of acceptable behavior in the larger social system in which they are a part," (Matthews, 1993: 350).

Legitimation and the search for approval are also commonly characterized as the fulfillment of a "social contract[76]" between the business and society (Branco and Rodriguez, 2006; Huang & Kung, 2010). The actions that constitute legitimation strategies are particularly important for businesses, but they do not necessarily entail attempts to woo societal favor. Wood and Jones

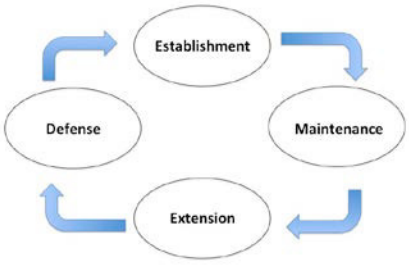
[76] Although it may not be explicitly and officially stated, a social contract constitutes those mutual responsibilities that members of a society must respect and execute in order for that society to function. For example, in most societies worldwide, individuals and institutions have a mutual responsibility to develop the next generation to lead the world, to preserve environmental bounty for posterity and future use as well as to take care of the sick and otherwise disadvantaged. Social contracts have binding power in that they provide sufficient justification for stakeholders to permit or veto firm operations (Huang and Kung, 2010). This highlights the fact that the source of firm legitimacy lies primarily outside of the firm.

(1995) explain that the methods businesses use to legitimate themselves depend on which stakeholder they want to address, and Branco and Rodriguez (2006: 236) add that "high visibility" industries and those with a big environmental impact are under more pressure to legitimate themselves, particularly by disclosing more CSR information than the competition. Lindbloom (1994, cited in Gary et al., 1996) outlines four possible legitimation strategies that firms may adopt when their legitimacy is in question:

1. Seek to educate stakeholders about the organization's intentions to improve performance.
2. Seek to change the organization's perception of the event (without changing performance).
3. Distract attention away from the issue of concern.
4. Seek to change external expectations of the organization's performance.

The above strategies are salient when firms need to "repair" their legitimacy after a negative incident, but most businesses operate in a more neutral zone of "gaining" or "maintaining" their legitimacy (Suchman, 1995; O'Donovan, 2002). In general, these more neutral legitimation strategies involve public relations and publicity campaigns centered around laudable firm behavior. In particular, businesses publicize annual reports to emphasize the financial gains they generate for shareholders, or they report key environmental indicators and employee benefits. In the media, firms may purchase ad space to build public awareness of their philanthropic work. They may also emphasize the number of local people they employ to win hearts and minds. Legitimacy enhancing activities may also precede incidents, including pending environmental legislation or stricter regulations, in order to mitigate the negative impact of these changes (Huang & Kung, 2010). In sum, legitimation can be described as a dynamic, cyclical process that describes how businesses respond to varying levels of societal approval; some scholars label stages in this process according to whether a firm is "gaining," "maintaining," or "repairing" its legitimacy status. Similarly, Figure 6 depicts legitimation as a four-stage process:

Figure 16: Four stages of legitimacy



Source: Tilling, 2004

Again, social acceptance of a firm is not just abstract or psychological; a key motivation for firms pursuing legitimation is to gain access to resources. Resources are "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by the firm" (Barney, 1991: 101), which includes subsidies, property rights, and contracts from the public sector, patronage from customers, investment from the financial sector, and much more. Moreover, Hearit (1995) emphasizes that these resources that are "necessary for survival" are key indicators for *measuring* legitimacy. For example, the legitimacy of a business might be loosely calculated based on levels of consumer support, political approval, and other assets at a firm at different points in time or between multiple, comparable firms at the same point in time. Suchman (1995: 575-6) defines legitimacy itself as a resource that businesses need to operate. Finally, Hart (1995) broadens traditional notions of limited corporate resources by focusing on environmental resources and environmental services in the firm; during a crisis of legitimacy, for example, a business might lose its privileges to use local environmental services (like water for waste disposal).

Legitimacy theory helps to conceptualize how and why firms seek societal approval. The following paragraphs explain stakeholder theory, which explores the constituents of societal approval and how businesses keep track and prioritize which societal cues merit a response. While many of the examples of CSR, corporate citizenship and legitimation described above involve disclosure, philanthropy and public relations work, this research focuses on initiatives that require less superficial measures; investment into environmental technology and environmental practices take capital, expertise, and operational adjustments, and only the most significant stakeholders and pressures to legitimize will bring about this level of commitment.

3.4 Stakeholder Theory

Stakeholder theory explains more deeply the makeup of groups with the power to grant or deny societal approval and thereby control the flow of crucial resources to and away from the firm. In Freeman's (1984) groundbreaking work on the subject, he defines stakeholders as groups or individuals that are affected by corporate actions and may affect the corporation in turn. He also quotes the Stanford Research Institute in an international memorandum that states that stakeholders are "those groups without whose support the organization would cease to

exist." The term "primary stakeholder" is typically reserved for those groups that interact directly with the firm and control the resources on which it depends, while "secondary stakeholders" make no transactions with the firm but still feel its impact (Mitchell et al., 1997; Moir, 2001). Still, regardless of their primary or secondary status, all stakeholders are also said to have *intrinsic value* in that their needs and concerns warrant consideration regardless of the effects on a business (Donaldson & Preston, 1995).

According to stakeholder theory, corporate environmental behavior results from a nexus of contracts between companies and their stakeholders, especially when the success of the corporation hinges on fulfilling these formal or informal contracts.[77] In other words, corporations have the duty to respect the rights of stakeholders as a matter of legal and moral principle. First, with respect to legal contracts, an increasing number of stakeholder groups can point to laws that defend their interests (and counteract the corporate mode of prioritizing shareholder interests). For instance, EPA emissions standards constrain companies by holding them accountable for polluting externalities and help to protect the valuable natural resources on which communities depend. Labor laws that uphold a minimum wage and counteract discriminatory practices also take care of employee stakeholders. By contrast, informal contracts based on a moral obligation follow the same logic as firms' search for congruence with societal norms, i.e., the legitimation process. Given the diversity of primary and secondary stakeholders, however, as well as the possibility that their desires and expectations may conflict, a key component of the literature involves identifying and evaluating the relative strength of different stakeholder groups.

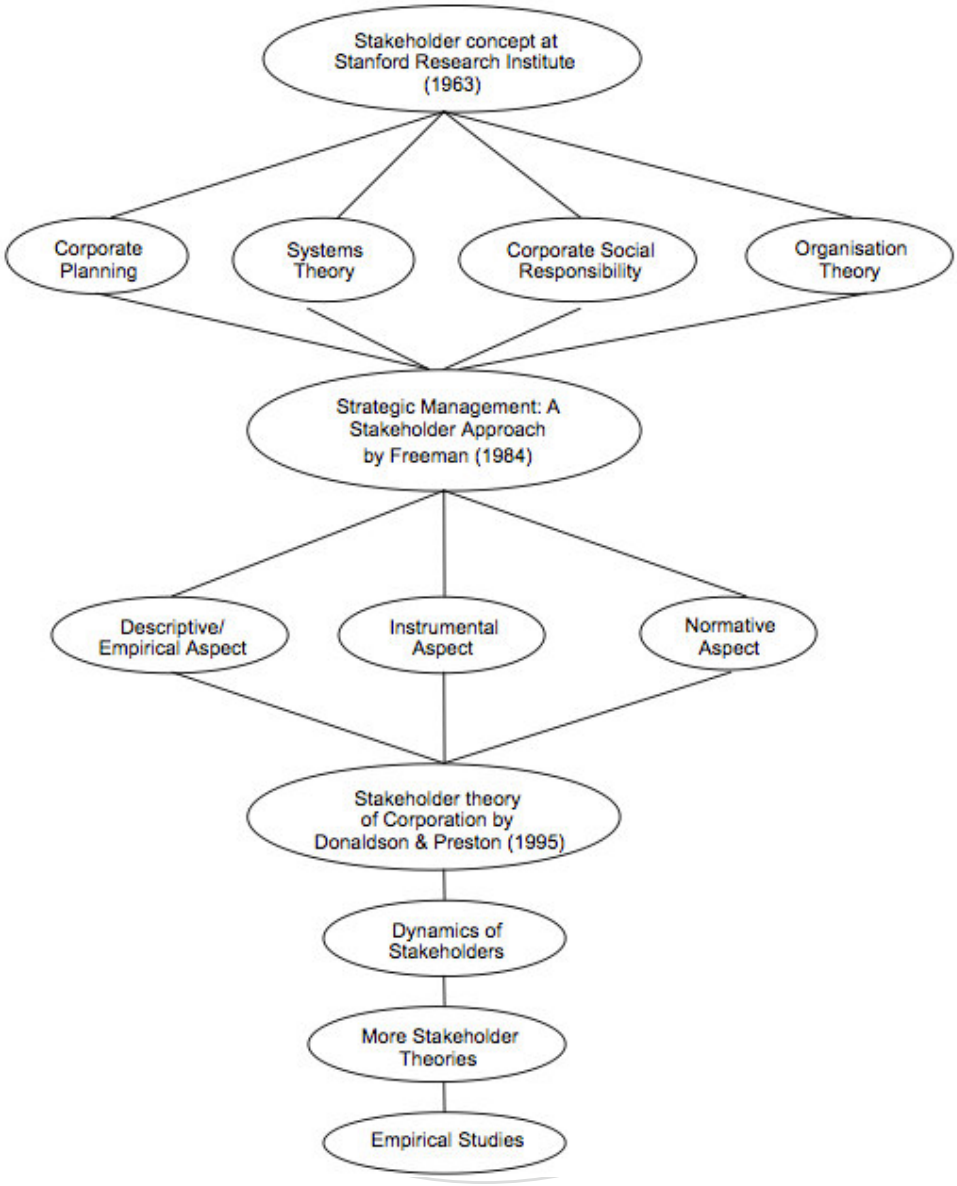
Moir (2001) calls this important component of stakeholder theory research "stakeholder salience." One theory of stakeholder salience focuses on three characteristics that different groups possess in unequal amounts: power, legitimacy and urgency (Mitchell et al., 1997; Agle et al., 1999). With respect to stakeholders with a sense of urgency, Huang and Kung (2010) suggest that stakeholders with strong economic interests affected by firm behavior are more likely to impact firm decision making. Thus, the most powerful campaigns to enhance corporate environmental investment might promote such investment as a matter of economic necessity. Using a similar reasoning, Freeman (1988) identifies six critical stakeholders for corporate

[77] Moir (2001) explains social contract theory as another theory of CSR decision making separate from stakeholder theory, but the same principles and even terminology are employed across the field of literature.

management: owners (especially shareholders), suppliers, employees, customers, the local community, and managers. In this study, stakeholder groups fall into different categories based on which sector they belong to, and their relative salience in corporate decision-making is explored in the discussion section.

Legitimacy theory and stakeholder theory arguably involve some inherent theoretical limitations that hinder their usefulness in this study. In his 1988 essay about stakeholder theory, Freeman asserts that his idea has a "normative core" — it describes managerial capitalism as it ought to be rather than as it is. Thus, stakeholder theory is a useful idea for conceptualizing the societal *potential* of a corporation, but a normative theoretical focus is inherently unscientific if the question at hand pertains to the nature of the decision-making process in corporations. Although a society with developed social and environmental consciousness may conceive of corporate behavior in this way, social and environmental values have relatively little impact in a corporate paradigm that — as a matter of fact *and* a matter of law — must prioritize maximum profitability. Legitimacy theory could fall victim to the same wishful thinking. Although the theory implies the more rational model of resources flowing from happy stakeholders to corporations, the theory still employs shades of normativity that fail to convincingly explain corporate behavior. At the heart of the matter, companies stay in business in order to make money, not in order to establish their legitimacy. If legitimacy, like stakeholder rights, enters into the minds of corporate managers at all, it is likely a secondary and supplementary concern to the impetus to make enough money to stay in business and prosper. Still, these theories — especially in their descriptive iterations — offer the most comprehensive and compelling explanations for corporate behavior in the literature.

Figure 17: Evolution of stakeholder theory



Source: Elias et.al, 2001

3.5 Intervening variables

Descriptive research into CSR behavior also discusses factors that influence environmental investment decision making besides stakeholder influence and firm legitimation. For instance, some research has discovered strong linkages between CSR and management, i.e., the personality or personal philosophy of CEOs (Campbell, 2002; Papasolomou-Doukadis et al.,

2005). Corbett and Kirsch (2009) assert that companies with ISO 9000[78] certification are more likely to attain ISO 14001, and vice versa, suggesting that the ISO regulatory process itself may induce environmental upgrades in steel and other industries.

Whether or not a firm is part of a high-growth industry also affects its likelihood of investing more capital into environmental initiatives; high-growth industries are characterized by quicker technology development and turnover and a more fluid, innovation-driven management style (Russo & Fouts, 1997). The argument that CSR investment increases along with (and as a result of) corporate research and technology development initiatives follows a similar path of reasoning as studies looking at the role of ISO certification. Although R&D may involve environmental protection-oriented technologies, it mostly centers around product innovation (McWilliams & Siegel, 2001). McWilliams and Siegel (2000) contend that, in the majority of studies that established a positive relationship between CSR and financial performance since the 1970s, many of them failed to take into account the role of R&D as a possible confounding factor. Moreover, industry type also influences the effect of corporate social performance on financial performance in firms in Taiwan (Yang et al., 2010). McWilliams and Siegel (2001) also hypothesize that firms selling an experience (e.g., restaurants, theme parks) are more likely to rely on their reputation to attract costumers, which makes CSR efforts more important for them; the same applies to those industries that attract more affluent customers who are willing to pay extra for CSR.

Environmental disclosure studies often use approaches other than stakeholder theory to identify what influences firms' public accounting strategies. Suttipan and Stanton (2012) determined that company size — measured in terms of sales revenue — was the only explanatory variable able to predict levels of environmental disclosure in corporate annual reports.[79] The bigger the corporation, the more likely they are to release information about their environmental impact to the public. Huang and Kung (2010) explain the effect of size using the "political cost hypothesis." This hypothesis presumes that high revenues (or other common indicators of size) generate attention among the public, and greater visibility makes corporate actions more politically sensitive. In other words, under heightened scrutiny, larger companies

[78] The ISO 9000 series encompasses a set of prescriptions for quality management systems.
[79] They also tested industry type, ownership status (international or domestic), country of origin, and profitability (in terms of net profits).

feel more pressure to reform or else bear the political cost of perceived negligence, i.e., the cost of regulatory sanctions or consumer sanctions (like boycotts). Furthermore, profitable companies with "slack resource availability" are typically more likely to launch CSR initiatives (Waddock & Graves, 1997). Hossain et al. (1994) determined that size, financial leverage and foreign listing status all had a significant positive impact on voluntary disclosure.

Despite the popularity of company size as a significant indicator of corporate environmental behavior, size is not an adequate explanatory variable because of the market-based and legitimacy-related context that gives it meaning. In other words, companies would not inherently improve their environmental records as they increased in size were it not for the commercial pressures that induce this behavior. Furthermore, the relationship between high net revenues and increased environmental disclosure becomes even more muddied when considering Huang and Kung's (2010) work on high profitability and disclosure. Huang and Kung found that high profitability among firms on the Taiwan Stock Exchange significantly *decreased* the probability that they would disclose environmental information about their company. They explain that lower-profit companies might feel pressure to increase their environmental reporting in order to gain competitive advantage with eco-friendly branding. Blomback and Wigren (2009) add that a prevailing research trend that highlights size as a critical factor and treats "small firm CSR" through a different lens has made discourse on the subject less nuanced and persuasive.

4. Results

The results of my survey and interviews uncover an industry of steel-producing electric arc furnaces with very similar environmental protocols, technologies, as well as a focus on current and impending public-sector regulation, ISO certification, and a sensitivity to cost-benefit tradeoffs. Another defining feature of the industry seems to be an activist private sector advocate in the Taiwan Steel and Iron Industry Association, which acts as a go-between for industry and the government and also reduces the transaction costs involved in researching and designing environmental protection systems as well as vetting purveyors of environmental protection services, particularly companies that handle waste disposal. The paragraphs that follow will explore the interview testimony on these themes, but first, the data from the survey instrument poses some interesting questions for future research.

The structure of the survey instrument includes three main sections. First, companies give

some general information about themselves such as the year they were established, their ISO certification status, their number of employees, and whether or not they produce for export. Next, they go through a list of Best Available Techniques for environmental protection in EAF production and indicate which technologies and protocols their factory utilizes. Third, they gauge the pressure they feel from various agents in the private, public and voluntary sectors (as well as from intervening variable agents like existing R&D efforts and company size), according to levels on a Likert scale. Unfortunately, this survey methodology elicits some concerns about its findings. For one, the relative lack of responses poses problems for the generalizability of the data; in all, I collected five complete surveys from within Taiwan's EAF industry plus one incomplete EAF survey, a complete survey from the China Steel group and an incomplete survey from a steel conglomerate with operations based overseas. Also, in the pivotal section of the survey that attempts to weigh varying levels of pressure from different sector agents, each company tended to identify sources of pressure from nearly every indicator at comparable levels. These more-or-less interchangeable results reduced further the potential for finding a quantitative basis for correlating sector pressure with varying levels of environmental investment, accounting for firm size, profitability and other factors. Thus, what follows in Table 4 is not a quantitative analysis of the data at all, but a faithful representation of survey results and response ranges, followed by interview data to shed light on the remaining gray areas.

Table 4: Collated survey data by indicator ranges

Average score of indicator	*Sector averages*	*Indicators (values)*
3-3.5	Public sector: 3 Private sector: 3.4 Intervening variable: 3.5	Gov't subsidies (3) Accounting firms (3.4) Debt holders (3.4) Company age (3.5)
3.5+-4	Voluntary sector: 3.93 Public sector: 3.9 Private sector: 4	Citizen groups (3.8) EPA awards (3.8) Lawsuits (4) Public hearings (4) EPA tech support (4) Customers (4)

4+-4.5	Intervening variable: 4.2 Voluntary sector:4.3 Private sector: 4.31 Public sector: 4.4	Routine upgrades (4.2) Media (4.2) Investors (4.2) Int'l factory norms (4.25) Neighbors (4.4) EIA (4.4) EPA voluntary regs (4.4) Managers (4.4) Employees (4.4)
4.5+-5	Intervening variable: 4.6 Voluntary Sector: 4.6 Private sector: 4.68 Public sector: 4.7	Company size (4.6) Public protests (4.6) Future EPA regulations (4.6) Market competition (4.6) ISO, industry regs (4.75) EPA emissions regs (4.8)

Table 4 clearly shows the limited range of responses generated by the multi-sector indicators portion of the survey. In fact, only one company disagreed that a single indicator (government subsidies) impacted their environmental protection protocols. To address this issue, future iterations of the survey might include a broader range of Likert scale values. For instance, rather than a five-point scale where "4" equals "agree" and "5" equals "strongly agree," another survey might use an 11-point scale and have firms differentiate the degree of pressure they feel from "0," meaning no pressure, to "10," meaning strong and unrelenting pressure from a particular indicator. Still, it's interesting to note how, on average, firms agreed that 19 out of 25 indicators impacted their environmental protection efforts (averages below "4" indicate that most firms neither agreed nor disagreed that a particular indicator impacted their protocols). EAF steel firms feel, or want to convey that they feel, pressure to be environmentally responsible from all sides and all sectors.

Looking at the data another way, certain indicators point to a slightly wider variety of responses than others. For instance, every firm agreed on some level that the following indicators affected their environmental investment levels: routine upgrades, company size, neighbors, the

media, public protests, lawsuits, voluntary EPA regulations, environmental impact assessments, current EPA emissions standards, future EPA regulations, market competition, management, and investors. By contrast, all other indicators elicited at least one response neither in agreement or disagreement about the indicator's impact — a neutral response — or at least one company did not know about the particular indicator. Of course, the minuscule sample size does not allow for any meaningful statistical correlation between these discrepancies and, for example, company size or experience. This offers another opportunity for future research, including the search for more insight through interviews with companies. Sadly, each of these companies expressed a lack of human resources and time to field interview questions about the subject matter, and the bulk of this study's non-survey qualitative data about EAF firms comes from industry representatives that work closely with them and on their behalf as technology consultants and steel industry specialists.

Regarding the middle portion of the survey, EAF firm respondents varied much more widely with respect to the number of recommended environmental protection techniques and equipment they utilized. Judging purely from the number of different protocols utilized, one company identified 22 out of a maximum of 29 environmental protection methods, while the other companies confirmed 17, 16, 16, and 11, respectively. This data suggests a fairly broad range of EMS development levels in the EAF sector, however, this data is not clearly related to company factors like size, age, or target market (import/export).[80] Looking at the areas with the broadest agreement, we can conclude that avoiding mercury, closed-loop water-based cooling systems, and distributing production residues for use elsewhere are techniques practiced by every surveyed company. Several industry-level interviewees elaborated on these and more revealing environmental investment trends.

First, TSIIA General Secretary Jerry Huang emphasized that, while EAF investment levels are not completely standardized, they are very similar when it comes to the biggest environmental concern for the industry: waste collection and disposal. Huang explains that, whereas 30 years ago EAF plants used scrubber technologies for their hazardous powder waste, this technology failed across the board and had to be replaced by a bag house system to conform

[80] Unfortunately the scale designed to capture the differences between company revenues was invalid. This scale was based on a general scale of Taiwanese SMEs and did not consider the higher revenue-generating capacity of heavy industry SMEs.

to increasingly rigid government regulations. Thus, nowadays Taiwan's EAF facilities collect this dust through either a canopy hood or a (more costly, but more effective) total evacuation system that sequesters hazardous waste into a separate facility containing a bag filter. Of the 21 EAF firms on the island, however, only one company — Dragon Steel, a subsidiary of China Steel — has the facilities for in-house treatment of this hazardous waste. Also, including the Dragon Steel facility, Taiwan has only a total of three facilities capable of this work. A facility in Taoyuan handles much of the waste coming from Northern Taiwan, while Taiwan Steel Union, in Changhua County, offers the cheapest[81] hazardous waste treatment services. Importantly, Taiwan Steel Union was implicated in the serious dioxin contamination incident of 2009 involving tainted duck meat (explored in Section 2.5). Therefore, of the six total stages of waste management (see Section 2.2, Figure 1), the vast majority of EAF facilities are only responsible for the first two steps: waste collection and storage. The crucial final stages of the waste management process are arguably out of their hands, especially considering such a narrow field of companies offering these services.

The same cannot be said for non-hazardous EAF waste management, i.e., treatment and disposal or reuse of EAF slag. These companies must handle the slag they generate differently from carcinogenic EAF powder. First they must separate it according to when it was generated during steel production, as different production stages create slag with distinct physical properties that are more suited to being reused in different final products (e.g., cement versus higher-quality construction materials). Huang recalled how the standard procedure of separating slag came to be after TSIIA agents visited each EAF steel plant and got them to commit to it. In addition, the TSIIA also monitors slag treatment facilities — of which there are more than double the number of EAF dust treatment facilities — and makes strong recommendations to EAF firms about which facilities' services they should employ (based in part on these treatment facilities' environmental protection records). For example, Huang recalls that in 2012 TSIIA organized EAF firms to sign an agreement not to do business with a particular waste treatment company that had been caught cutting corners in the execution of its duties.

Also beyond the reach of the survey data, General Secretary Huang stated in November 2014

[81] Huang also noted in November 2014 that the price for treating dust is currently decreasing.

that 14 EAF firms (70%) are certified according to the ISO 14000 standards.[82] Also, all EAF facilities in Taiwan use continuous casting, all recycle gray water in their cooling systems, and all interact on some level with TSIIA's specialized committees that are hired to research and audit environmental protection efforts and distribute the findings. In addition, Huang notes that 20% of EAF facilities are housed in industrial parks, while the rest are in "industrial areas," and all are hooked into the national Taipower energy grid. The location of the facilities matters immensely when it comes to public sector pressure for environmental protection, as some local governments are much tougher and inspect factories more frequently than others. Huang explains that facilities in Kaohsiung must undergo daily audits via automatic environmental monitoring devices that report their data directly to local regulators. Furthermore, regional environmental protection bureau patrols regularly respond to calls from the neighbors of industry, and they are required to investigate any issues.

The efficacy of government monitoring and regulation garnered plenty of input from interview subjects, in academia especially. Dr. Tu Wen-ling, an associate professor in the department of public administration at National Chengchi University, emphasized the likelihood that government outsourcing of environmental monitoring services to agents funded by the private sector might result in biased, unreliable data that favors industry; her research into a coal-fired power plant in Taichung provided evidence for this bias. The issue of government outsourcing of administrative duties highlights another principle concern voiced by Dr. Tu and Dr. William Su, a former environmental law professor at National Chung Hsing University in Taichung: discrepancies between EPA promises and their administrative capacity. Both professors described the national agency as an adopter and vocal proponent of internationally competitive environmental standards, but stated bluntly that their monitoring abilities and enforcement practices are not up to the task of ensuring that domestic industries reach these standards, either for lack of funds (Dr. Su) or for lack of will (Dr. Tu). According to Dr. Su, Taiwan's EPA system is still caught in a "command and control" administrative mode that requires immense inputs of human resources and funding to operate, whereas the foundation of a more cost-effective emissions trading system (that would transfer much of the cost of

[82] During the first two or three years in which ISO 14000 entered the industrial sector, the government did provide a subsidy to China Steel and Donghe Steel, but Huang believes this impact was minimal for SME steel companies.

environmental regulation administration to the private sector) has languished in government for 15 years. This view, of course, contrasts with that of activists and academics like Dr. Tu, who distrust private sector self-regulation.

In addition, Dr. Tu discovered a discrepancy between the data that privately funded monitoring firms collected and their policy recommendations; in particular, energy sector monitors apparently acknowledged worrisome levels of PM2.5 without following up with lawmakers to address the issue via policy changes. This suggests that environmental monitoring data might not have the same impact on policy as, for example, environmental standards adopted in other countries. Furthermore, Dr. Tu commented that the leadership of Taiwan's EPA in 2013 regularly made public statements about the importance of balancing environmental protection with economic growth considerations, which might introduce some bias into the execution of the EPA's administrative responsibilities. In sum, this testimony suggests that although EAF companies and industry representatives (Sinotech, TSIIA) highlight public sector indicators – particularly regulation – as an important coercive impetus for environmental upgrades, the regulatory system is not flawless and steel industry firms have some opportunities to take advantage of administrative inadequacies.

Regarding the voluntary sector indicators highlighted in the survey instrument and interviews, one environmental activist focused on petrochemical companies in Taiwan cited the increased participation of voluntary sector groups in public hearings and EIA processes beginning in the mid-1990s, which she claimed has given neighborhood and issue-based groups more leverage in pressuring all kinds of industries, including steel. Dr. Tu also mentioned this impact, adding that environmental groups such as Citizens of the Earth have been increasingly successful in reaching the public at large with low-cost grassroots monitoring (for instance, taking photographs daily over long periods of time to gauge basic air quality conditions) and other methods. All of these factors could potentially impact EAF companies, but it's important to note that none of the academic or NGO representatives interviewed for this study had direct experience with the steel industry.

Lastly, each interviewee from each sector stressed the truism that EAF companies' decision-making process must ultimately utilize a cost-benefit analysis, but these individuals disagreed about the extent to which multi-sector indicators impacted this analysis. Uniquely, a representative from China Steel conveyed that company's approach to CSR and environmental

protection as a source of competitive advantage:

> "CSC wishes to become one of the most environment-friendly steel company (sic) in the world. Please refer to our CSR reports. However, all investments need to consider economic, technical and practical feasibility. So we will do it if an investment:
> 1. Needs relatively lower capital and has huge environmental benefit
> 2. Is global trend and the cost is affordable
> 3. Has IRR [internal rate of return] higher than CSC's benchmark"

The search for competitive advantage via environmental investment indicates a heavy private sector-based impetus. Notably, representatives from Sinotech engineering and TSIIA contradict the relatively high level of EAF firm agreement in the survey regarding competition and customer expectations as positive sources of pressure for green investment. Huang stated that customers, even customers abroad, "don't care" about environmental performance provided that they receive good value and reliable service for a reasonable price.

This input goes a long way toward fleshing out the foundations of EAF investment levels into environmental protection. The discussion section that follows builds on the integration of survey data with interview testimony to shed light on the possible connections between indicators of multi-sector pressure and EAF investment (as well as the role of intervening variables), how legitimacy and stakeholder theories can explain these connections, and how to square these theories with the cost-benefit analysis reality behind firm decision-making.

5. Discussion

The tendency of surveyed EAF firms to point to the majority of stakeholder indicators as influencers in their environmental investment decision-making suggests that these firms are highly sensitive to societal mores and pressures — a key facet of CSR according to theorists. Whether or not each indicator truly does impact firm decisions, though, a high degree of perceived social responsiveness is important as a legitimation strategy, particularly for firms whose negative externalities include cancer-causing agents like dioxins. Social responsiveness implies recognition that the company's actions are integrated within a dynamic network encompassing a wide variety of stakeholders. The following paragraphs explore how influential stakeholders (as determined through the survey instrument and supported by subsequent interviews) may impact a firm's cost-benefit calculus through inciting the will to seek legitimacy

and secure the resources that legitimacy implies.

First, the survey indicator that elicited the strongest agreement over decision-making impact, and the most prominent issue raised by interview subjects, involves public sector emissions standards. This indicator, along with impending EPA regulations, likely triggers strong approval-seeking behaviors from corporations because of the legal and financial consequences of falling short of public sector expectations. Huang (2001) mentions the special significance of fines for SME companies, as the amount of the fines corresponds with the severity of the environmental problem rather than the size of the company.[83] Again, corporations are keenly motivated to maintain their legitimacy and to hold on to their resources (i.e., their profitability), while extensive fines, a criminal investigation, or the mandated suspension of operations has the potential to wreak havoc on a business. This is not merely due to the financial impact of regulatory enforcement. The loss of financial and reputational resources incurred by government action also has ripple effects. Government action might stimulate neighborhood groups or environmentalists into action. Media coverage could reach current and potential investors. Government action might even spur on banks to call in loans, as was recently the case for Ting Hsin Corp. following its involvement in a tainted food scandal in late 2014.

Although some environmentalists and academics in particular focus on the weaknesses of environmental protection emanating from the government, the public sector is undeniably a legitimating force in Taiwan. The power it wields in administering environmental impact assessments controls whether or not companies can expand their operations — which effectively creates a potential ceiling for their future earnings. Furthermore, unlike its counterparts in many developing countries, Taiwan's EPA has reached a level of regulatory and bureaucratic development comparable to industrialized nations with a 20-year head start. Thus, government action taken against a firm can also have repercussions even beyond Taiwan and in the international market, since international investors and customers recognize the power the government has to threaten a corporation's economic viability. By the same token, these private sector actors can also point to EPA accolades as a legitimating factor for Taiwanese steel firms and a sign that recipients are unlikely to incur extreme regulatory sanction in the foreseeable future. The same goes for voluntary regulatory schemes such as participation in the Greenhouse

[83] Huang Wei-min, a representative of the EPA's air quality control department, confirmed this fact in an email sent Dec. 20, 2014.

Reduction Act and carbon footprint labeling.

Indeed, customers and investors are important stakeholders in the literature, and surveyed firms generally point to both as a source of pressure for environmental upgrades. Heavy industries, as opposed to manufacturers of consumer goods, have special considerations when it comes to luring customers and investment. For one, customers typically buy in large bulk orders for big construction projects or to satisfy regular demand for steel further along the supply chain. This signifies that heavy industry firms typically function by attracting fewer high-value contracts than would a business producing for mass appeal in the general consumer market. With profitability relying on relatively fewer large transactions, however, each contract becomes more important to company profits and to shareholders' rate of return. Thus, customers and potential customers in need of a reliable source of steel will be more likely to turn to a reputable company with evidence of long-term stability. Shareholders also prize stable companies with consistently high rates of return, and so companies must aim to stay at least in the "maintenance" stage of the legitimation process (Suchman, 1995; O'Donovan, 2002; Tilling, 2004) to lure investment. Besides the legitimacy that businesses acquire via compliance with EPA regulations and EPA accolades, independent industry standards such as ISO 14000 were also highlighted in the survey instrument and interviews as a key source of EAF firm legitimacy.

Unlike firm legitimation via public sector initiatives, ISO 14000 certification doesn't work by levying fines or threatening companies with criminal investigation and other direct offenses to a business' bottom line. Instead, ISO 14000 operates as a kind of status symbol that increases firm marketability by assigning it comparable status to effective corporate EMS around the world. In other words, the 70% of EAF firms in Taiwan with ISO certification have garnered a form of competitive advantage against other firms in the market. In addition to the environmental protection benefits signified by ISO 14000, the demands of keeping the certification over long periods also indicate that ISO companies employ highly efficient management practices focused on long-term improvement. Coupled with the decreased likelihood of regulatory sanction, ISO 14000 (and 9000) certification communicate stability, an optimizing orientation, and effective management in EAF firms — all of which are attractive to stakeholders wanting to do business or invest in the steel industry.

The final set of indicators worthy of mention from the private sector operate within the business itself: managers and employees. Ultimately, all corporate decision making regarding

environmental investment comes down to managers empowered to direct corporate capital and shift company practices. These managers must be primarily concerned with the economic viability of their enterprise, but a manager's understanding of environmental protection as a competitive advantage, or even a manager's personal conviction about the importance of environmental protection and its compatibility with profit-making, can potentially revolutionize the way a company conducts its business. Mission-centered managers are uniquely empowered to exercise a process of legitimation based not on congruence with external stakeholders' values and expectations but chiefly with their own set of ethical mores. Moreover, as a generation of youth raised in an era of increased environmental education and action enters the workforce, companies may need to emphasize their environmental record in order to attract the best candidates for open positions. Perhaps more than at any other point in history, individuals are pursuing work in line with their personal values and convictions, searching for a sense of meaning and morale as well as a paycheck. These highly qualified, highly motivated employees are pivotal to the overall economic success of an enterprise.

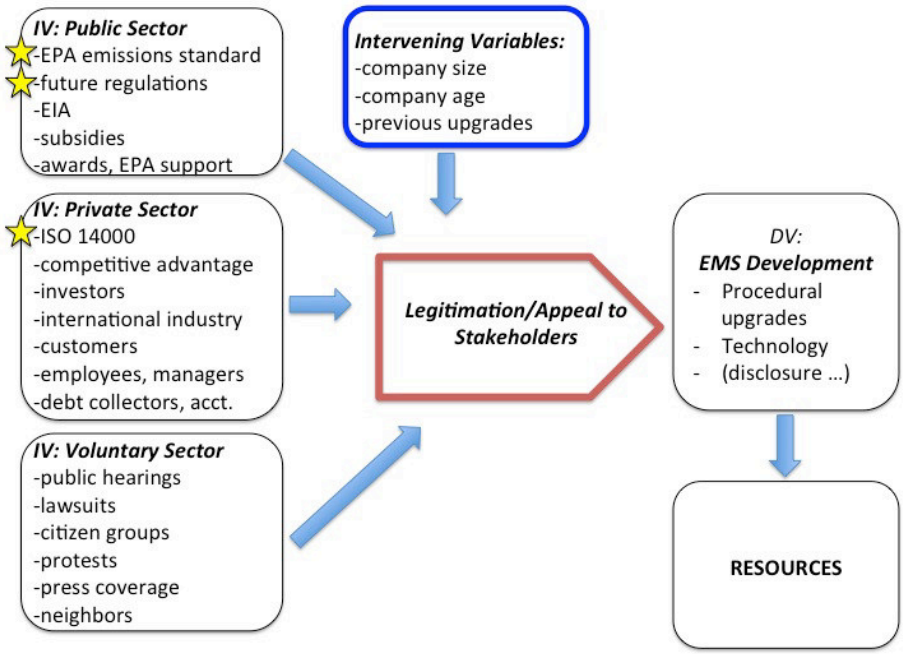
Although arguably possessing much less control over the financial resources companies require to survive, voluntary sector initiatives are also an important aspect of EAF firms' legitimation strategies. Most surveyed companies agreed that the threat of lawsuits compels them to upgrade environmental technology and practices. As was mentioned in Section 2.5, some nongovernmental organizations like Wild at Heart and the Environmental Jurists Association exist to make it easier for community groups to sue corporations to protect their health and land. Organized citizens groups, neighborhood associations and self-help organizations also bind together to limit the transaction costs incurred by members seeking to impact a company's bottom line. Lengthy and costly lawsuits definitely offer a strong disincentive for insufficient EMS, but most voluntary sector action affects companies' profit margins only indirectly. Press coverage, for example, not only implies the possible dissemination of information endangering corporate legitimacy to the general public; companies also risk this information getting to current and potential customers and shareholders as well. Similarly, public hearings and protests (that may or may not be covered in the general media) can have a strong impact on the private and public sector stakeholders with more potential impact on firm profitability.

Finally, whereas the preceding discussion centered around stakeholder impact on corporate legitimation strategies centered on resource accumulation and safeguarding,

intervening variables might affect firms in other ways. The most prominent intervening variable, company size, was discussed and critiqued earlier in Section 3.5 and the same interpretation applies here. In addition, small- and medium-sized enterprises like EAF minimills might have less institutional inertia, meaning they would be generally easier to change. With respect to industry type, although in general steel manufacturing is a high-visibility industry as defined by Branco and Rodriguez (2006), the industry subcategory of electric arc furnace facilities does not garner the same level of visibility in the public at large. This could actually result in *less* pressure on firms to upgrade their EMS. Similarly, the age of a company might also indicate its level of experience and expertise in conducting system upgrades, lessening the psychological pressure to enhance EMS while increasing a business' capacity to do so. And, of course, EAF facility upgrades are rarely exclusively related to environmental protection (versus quality control or efficiency enhancement upgrades, for example), but the latest techniques and technologies are often designed with environmental implications in mind. Indeed, each surveyed company agreed with the statement that "Environmental upgrades are the result of routine factory upgrades."

Figure 18 shows a conceptual framework for this study that integrates the theoretical basis of the research with survey and interview results. The most prominent sources of firm legitimacy within the political ecosystem/environmental governance structure of EAF steel production are highlighted.

Figure 18: Conceptual framework of legitimation pressures in EMS development



6. Conclusion

According to this research concerning pressures to increase EMS development in Taiwan's steel industry and electric arc furnaces in particular, companies engage in procedural and technological upgrades primarily as a result of current and impending government regulations, and prior experience conforming to international standards (like ISO 9000 and ISO 14000) further predispose companies to invest. With relatively minimal involvement from the voluntary sector (compared to the food industry, semiconductor manufacturers, electroplating facilities and other industries facing periodic crises of legitimacy) and more relaxed expectations of environmental standards in the market (where price is king), public sector regulations are the primary provocateurs for proactive EMS, but a lack of robust administrative capabilities for inspection and enforcement across all regions of Taiwan can undercut overall progress.

This report has characterized progress in EMS as a process of legitimation, or approval-seeking, targeting stakeholders who control resources necessary for corporate survival. In the case of small- and medium-sized EAF enterprises in Taiwan, primarily financial resources controlled directly by customers and indirectly via government fines (and the more unlikely threat of suspended or discontinued operations and criminal prosecution) are chiefly what's at stake in corporate decision-making. Furthermore, knowledge, technical expertise and capital for investment are the primary tools necessary for successful efforts at legitimation via EMS.

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8.1 Appendix 1: Chinese-language survey (distributed)

跨部門因素對環境提升之影響全國調查問卷

首先，非常感謝您的協助。
此問卷係針對政府和私人企業在提升空氣品質的雙向合作為中心而設計，**希望能交由貴公司之相關部門專人填寫，並放入所附之回郵信封寄回**。
本匿名問卷需時約 15 分鐘，並僅止於學術分析使用，再次感謝您的協助。

Samantha Sprole
莎曼莎

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第一部分: 公司基本資料

公司名稱: _____

公司創立年份: 西元_____ 年

職員人數:
□ 1. <200
□ 2. 200—500
□ 3. 501—1000
□ 4. 1001—1500
□ 5. 1501—2000
□ 6. >2,000

銷售收入（年）

□ 1. <300,000 NTD
□ 2. 300,00 — 750,000
□ 3. 750,001 — 1,500,000
□ 4. 1,500,001 — 2,250,000
□ 5. 2,250,001 — 3,000,000
□ 6. 3,000,001 — 4,500,000
□ 7. 4,500,001 — 6,000,000
□ 8. 6,000,001 — 15,000,000
□ 9. 15,000,001 — 30,000,000
□ 10. >30,000,000

本公司製造下列產品請勾選所有符合之選項：

□ 1. 不鏽鋼
□ 2. 鋼捲
□ 3. 鋼管
□ 4. 鋼板
□ 5. 鋼條
□ 6. 其他: _____
_____
_____

本公司從事實體貨物外銷貿易?

□1. 是 □2.否 □3. 不清楚

本公司曾在最近五年內接到行政院環境保護署（以下簡稱「環保署」）執法者的處罰或罰元？

□1. 是 □2.否 □3. 不清楚

本公司曾在最近五年內接到環保署執法者的警告？

□1. 是 □2.否 □3. 不清楚

本公司已獲得ISO 9000認證。

□1. 是 □2.否 □3. 不清楚

第二部分：環保技術盤點調查
請檢視你們的環境管理系統，有使用的技術打(v)，無關者或未使用技術打(X)。
本問卷涉及貴公司機密，相關權責人員負保密責任。

電弧爐設施 (EAF Facilities)

1.空污預防與減量 Air emissions prevention and abatement

___避免含汞原料與副料 avoid raw materials and auxiliaries that contain mercury
___廢鋼預熱 scrap pre-heating in order to recover sensible heat from primary off gas
___ 集塵效率最佳化 optimize dust collection efficiency:
___抽氣與封蓋系統 combination of off-gas extraction and hood systems
___直接抽氣與集塵系統 direct gas extraction and doghouse systems
___ 直接抽氣與全屋抽氣系統 direct gas extraction and total building evacuation
___ 爐碴原地處理 on-site slag processing:
___ 爐碴破碎篩選裝置有效抽氣及淨化 efficient extraction of slag crusher and screening devices with subsequent off-gas cleansing
___以鏟車運送未處裡爐碴 transport of untreated slag by shovel loaders
___破碎物料輸送點之抽氣或調濕 extraction or wetting of conveyor transfer points for broken material
___爐碴貯存區調濕 wetting of slag storage heaps
___裝卸破碎爐碴使用水霧 use of water fogs when broken slag is loaded
___廢氣除塵袋達到低於 5mg 粉塵/Nm^3 （日平均值） Waste gas de-dusting bag filter achieving less than 5mg dust/Nm3 (daily mean value)
___過濾達到低於 15mg 粉塵/Nm^3 （日平均值）filter achieving less than 15mg dust/Nm3 (daily mean value)
___ 有機氧化合物(特別是 PCDD/F 與 PCB)減量 Minimization of organochlorine compounds, especially PCDD/F and PCB emissions
___排氣後燃室及驟冷 post-combustion within the off-gas duct system or in a separate post-combustion chamber with subsequent rapid quenching in order to avoid de novo synthesis
___驟冷 rapid quenching
___過濾器前注碳粉 injection of lignite powder into the duct before fabric filters
____其他 Other:
_____
_____
_____

2. 用水及廢水控制 Water usage and waste water control

___使用閉路回路水冷系統冷卻爐體裝置 use closed loop water cooling systems to cool
furnace devices

___連鑄廢水排放減量 minimize waste water discharge from continuous casting:

___以絮凝沉降和/或過濾去除固體 remove solids by flocculation, sedimentation, and/or filtration

___以浮除槽或其他有效裝置去除油脂 removal of oil in skimming tanks or other effective device

___冷卻水及真空泵水循環 recirculation of cooling water and water from vacuum generation

____其他 Other: _____

_____

_____

3. 殘碴減量 Minimization of production residues

___適當的收集與貯存以利特定處裡 appropriate collection and storage to facilitate a specific treatment

___耐火材回收與原地再用(及替代白雲石、菱鎂礦及石灰石) recovery and on-site recycling of refractory materials from the different processes for use internally (i.e. for substitution of dolomite, magnesite, and lime)

___集塵灰非鐵金屬(例如鋅)之場外回收 use of filter dusts for external recovery of non-ferrous metals (e.g. zinc)

___水處理工程之連鑄垢分離與回收(例如用於燒結爐/高爐或水泥工業) separation of scale from continuous casting in the water treatment process and recovery with subsequent recycling (e.g. for use in sinter/blast furnace or cement industry)

___爐碴與耐火材廢料之場外再利用 external use of refractory materials and slag from EAF process where market conditions allow for it

____其他 Other:

_____

_____

4.降低能耗 Reduce energy consumption

____使用連續成型鑄造 use continuous near net shape strip casting

____其他 Other:

_____

_____

第三部分: 請以下例程度回答問題:

非常不同意 不同意 無意見 同意 非常同 不清楚/不適用

---

1 2 3 4 5 6

1. 本公司重要投資者要求本公司提升我們的環境技術與實踐。
1 2 3 4 5 6

2. 國際鋼鐵行業的標準作業程式激勵本公司提升我們的環境技術與實踐。
1 2 3 4 5 6

3. 行業的獨立標準，例如ISO14001，激勵本公司提升我們的環境技術與實踐。
1 2 3 4 5 6

4. 客戶對本公司施加壓力，要求提升我們的環境技術與實踐。
1 2 3 4 5 6

5. 公司員工對本公司施加壓力，要求提升我們的環境技術與實踐。
1 2 3 4 5 6

6. 公司領導層和/或管理層優先考慮提升我們的環境技術與實踐。
1 2 3 4 5 6

7. 公司債權人對本公司施加壓力，要求提升我們的環境技術與實踐。
1 2 3 4 5 6

8. 公司的會計事務所對本公司施加壓力，要求提升我們的環境技術與實踐。
1 2 3 4 5 6

9. 擁有最好的環保技術和實務，讓鋼鐵企業在國際市場上更具競爭力。
1 2 3 4 5 6

10. 爲了遵守環保署的所有排放標準，本公司努力提升我們的環境技術與實踐。
1 2 3 4 5 6

11. 為了做好准備適應未來的法規，本公司努力提升我們的環境技術與實踐。
1 2 3 4 5 6

12. 爲了通過環境影響評估（EIA），本公司努力提升我們的環境技術與實踐。
1 2 3 4 5 6

13. 爲了獲得環保署嘉獎，本公司努力提升我們的環境技術與實踐。
1 2 3 4 5 6

14. 因為環保署自願監管計劃的激勵——例如，溫室氣體減量法以及碳足跡標籤等，本公司努力提升我們的環境技術與實踐。

1 2 3 4 5 6

15. 因為有了環保署及其專家網路提供的技術支持，本公司努力提升我們的環境技術與實踐。

1 2 3 4 5 6

16. 本公司獲得的政府補貼激勵我們努力提升環境技術與實踐。

1 2 3 4 5 6

17. 在公開聽證會上，與大眾和/或倡議團體的交流，促使本公司提升我們的環境技術和實踐。

1 2 3 4 5 6

18. 來自公民團體的壓力促使本公司減少對環境的衝擊。

1 2 3 4 5 6

19. 為了避免公眾或公民倡議團體的訴訟，本公司努力提升我們的環境技術和實踐。

1 2 3 4 5 6

20. 爲了避免公眾抗議，本公司努力提升我們的環境技術和實踐。

1 2 3 4 5 6

21. 為了避免來自媒體的負面報導，本公司努力提升我們的環境技術和實踐。

1 2 3 4 5 6

22. 來自鄰居的壓力促使本公司努力提升我們的環境技術和實踐。

1 2 3 4 5 6

23. 本公司的經營規模，促使我們努力提升我們的環境技術和實踐。

1 2 3 4 5 6

24. 本公司的經營時間的長短，促使我們提升我們的環境技術和實踐。

1 2 3 4 5 6

25. 工廠的常規升級是我們環境提升的原因。

1 2 3 4 5 6

第三部分: 如有任何關於本測驗的指教或意見，請您填寫於下列空白處。

非常感謝您的參與!

若您希望收到本研究的結果或提供其它意見，請與我聯絡。

Survey Number: _____

8.2 Appendix 2: English-language survey (reference)

NATIONAL SURVEY OF CROSS-SECTOR IMPACT ON ENVIRONMENTAL UPGRADES

Employees with responsibilities related to EPA regulation are heartily encouraged to participate in this national study of private and public sector efforts to maintain and improve Taiwan's air quality. The survey will take no more than 15 minutes of your time, and your responses will remain anonymous. The completed study will be made available to you upon request. Thank you again for your participation!

Please place the completed questionnaire in the envelope provided.

Samantha Sprole
International Master's Program in Asia-Pacific Studies
National Chengchi University
Taipei, Taiwan
+886 987 910 271
Samantha.sprole@gmail.com

Part 1: Please tell us a little about yourself and your company.

Company: _____

Age of company: _____ year(s)

Number of employees:
□ 1. <100
□ 2. 101—500
□ 3. 501—1000
□ 4. 1001—1500
□ 5. 1501—2000
□ 6. >2,001

Annual sales revenue:
□ 1. <300,000 NTD
□ 2. 300,00 — 750,000
□ 3. 750,001 — 1,500,000
□ 4. 1,500,001 — 2,250,000
□ 5. 2,250,001 — 3,000,000
□ 6. 3,000,001 — 4,500,000
□ 7. 4,500,001 — 6,000,000
□ 8. 6,000,001 — 15,000,000
□ 9. 15,000,001 — 30,000,000
□ 10. >30,000,000

Which products does your company make?
Check all that apply:
□ 1. Stainless steel
□ 2. Coil
□ 3. Tube
□ 4. Plate
□ 5. Bar
□ 6. Other: _____
_____
_____

My company produces for export □1. Yes □2. No □3. Don't know

My company has incurred EPA penalties or fines in the last five years. □1. Yes □2. No □3. Don't know

My company has received a warning from EPA regulators in the last five years. □1. Yes □2. No □3. Don't know

My company has achieved ISO 9000 certification. □1. Yes □2. No □3. Don't know

Part 2: Please evaluate the statements below according to the following scale:

Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree	Don't Know / NA
1	2	3	4	5	6

1. Important investors in my company demand that we upgrade our environmental technologies and practices.	1 2 3 4 5 6
2. The international steel industry's standard operating procedures motivate my company to upgrade our environmental technologies and practices.	1 2 3 4 5 6
3. Independent industry standards, like ISO14001, motivate my company to upgrade our environmental technologies and practices.	1 2 3 4 5 6
4. Our customers pressure this company to upgrade our environmental technologies and practices.	1 2 3 4 5 6
5. My company's employees pressure us to upgrade our environmental technologies and practices.	1 2 3 4 5 6
6. The leaders and/or managers in my company make it a priority to upgrade our environmental technologies and practices.	1 2 3 4 5 6
7. My company's debtors pressure us to upgrade our environmental technologies and practices.	1 2 3 4 5 6
8. My company's accounting firm(s) pressure us to upgrade our environmental technologies and practices.	1 2 3 4 5 6
9. Having the best environmental technologies and practices makes steel companies more competitive in the international market.	1 2 3 4 5 6
10. My company is motivated to upgrade its environmental technology and practices to comply with all Environmental Protection Administration's (EPA) emission standards.	1 2 3 4 5 6
11. My company is motivated to upgrade its environmental technology and practices in order to prepare for impending regulations.	1 2 3 4 5 6

12. My company is motivated to upgrade its environmental technologies and practices in order to pass Environmental Impact Assessments (EIA). 1 2 3 4 5 6

13. My company is motivated to upgrade its environmental technology and practices because of the EPA's environmental awards. 1 2 3 4 5 6

14. My company is motivated to upgrade its environmental technology and practices because of the EPA's voluntary regulatory schemes—for example, the Greenhouse Emissions Reduction Act and carbon footprint labeling. 1 2 3 4 5 6

15. My company is motivated to upgrade its environmental technology and practices thanks to technical support from the EPA and their network of experts. 1 2 3 4 5 6

16. My company receives government subsidies to encourage upgrades of environmental technology and practices. 1 2 3 4 5 6

17. Interacting with the general public and/or advocacy groups at public hearings motivates my company to upgrade our environmental technology and practices. 1 2 3 4 5 6

18. My company responds to pressure from organized citizen groups to reduce our environmental impact. 1 2 3 4 5 6

19. My company is motivated to upgrade its environmental technology and practices in order to avoid lawsuits from the public or from citizen advocacy groups. 1 2 3 4 5 6

20. My company is motivated to upgrade its environmental technology and practices in order to avoid public protests. 1 2 3 4 5 6

21. My company is motivated to upgrade its environmental technology and practices in order to avoid negative press coverage. 1 2 3 4 5 6

22. My company is motivated to upgrade its environmental technology and practices in response to pressure from our neighbors. 1 2 3 4 5 6

23. The size of my company motivates us to upgrade our environmental technologies and practices. 1 2 3 4 5 6

24. The age of my company motivates us to upgrade our environmental technologies and practices. 1 2 3 4 5 6

25. Environmental upgrades are the result of routine factory upgrades. 1 2 3 4 5 6

Part 3: Please write any additional comments you have regarding this survey in the space provided.

Thank you for participating in this research!

Your responses are very important to me. Please let me know if you have any further questions or comments, or if you would like to receive a copy of the finished study.

Survey Number: _____

8.3 Appendix 3: List of interviewees and survey participants

Interviewees:

Chang, Harry: National Chengchi University doctoral candidate and political activist
Chang, Shi-Long: Assistant Vice President at China Steel's Office of Energy and Environmental Affairs
Chao, Yu-Mei: General Manager of Dragon Steel's Environmental Protection Department
Ho, James C.S.: President of Katec R&D Corporation
Hsieh, Yein-Rui: Director General of Department of Air Quality Protection and Noise Control
Hsung-Hsiung Tsai: Minister of EPA 1996-2000
Huang, Jerry H.: Secretary General of Taiwan Steel and Iron Industries Association
Huang, Shu-Li: Director of Center for Global Change & Sustainability Science at National Taipei University
Lin, Echo: Secretary General of the Environmental Jurists Association
Lo, Chun: project manager for Sinotech Engineering Consultants
Lo, Chi-hao (James): reporter at The China Post with familial ties to steel industry
Su, Yi-Yuan (William): environmental law expert at National Chengchi University's Center for Security Studies
Tu, Wen-lin: professor of sociology at National Chengchi University
Winkler, Robin: founder of legal environmental defense organization Wild at Heart
Yeh, Shin-Cheng: Minister without Portfolio in Executive Yuan (member of thesis committee who contributed pertinent insight during thesis proposal and defense stages)

Survey Participants:

燁聯鋼鐵公司

海光企業公司

台灣機械公司重機廠

唐榮公司不銹鋼廠

榮剛重工公司

中鴻鋼鐵股份有限公司

中鋼公司 (China Steel, not part of study cohort)

Overseas Taiwanese steel firm wishes to remain anonymous.

8.4 Appendix 4: Domestic SME survey responses

Company: 燁聯鋼鐵公司 (14)

Year Founded: 1988

Employees: >2,000

Product(s):

- ☑ 1. 不鏽鋼
- ☑ 2. 鋼捲
- ☐ 3. 鋼管
- ☑ 4. 鋼板

Exports(?): yes

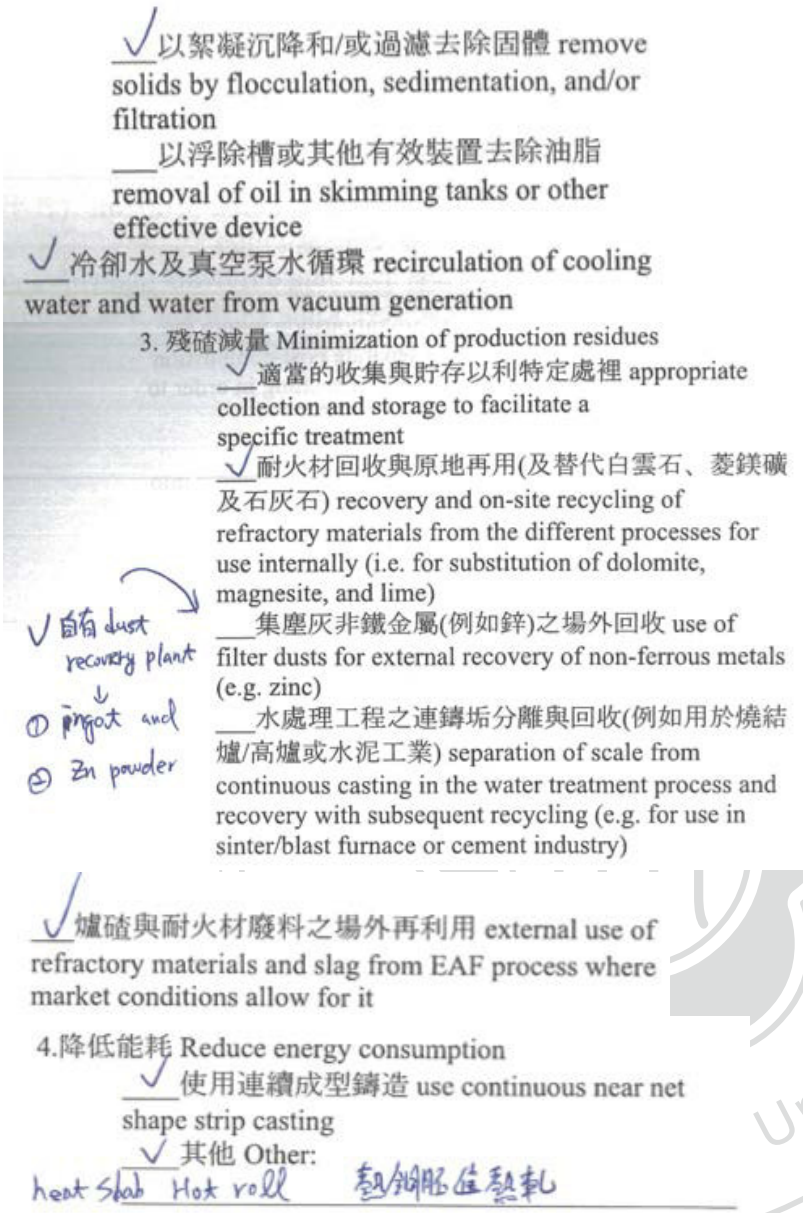
EPA penalties in the last 5 years(?): yes

EPA warning in the last 5 years(?): no

ISO 9000 certification(?): yes

1.空污預防與減量 Air emissions prevention and abatement
- √ 避免含汞原料與副料 avoid raw materials and auxiliaries that contain mercury
- ___ 廢鋼預熱 scrap pre-heating in order to recover sensible heat from primary off gas
- √ 集塵效率最佳化 optimize dust collection efficiency:
  - ___ 抽氣與封蓋系統 combination of off-gas extraction and hood systems
  - ___ 直接抽氣與集塵系統 direct gas extraction and doghouse systems
  - √ 直接抽氣與全屋抽氣系統 direct gas extraction and total building evacuation
- √ 爐碴原地處理 on-site slag processing:
  - ___ 爐碴破碎篩選裝置有效抽氣及淨化 efficient extraction of slag crusher and screening devices with subsequent off-gas cleansing
  - ___ 以鏟車運送未處裡爐碴 transport of untreated slag by shovel loaders
  - √ 破碎物料輸送點之抽氣或調濕 extraction or wetting of conveyor transfer points for broken material

2. 用水及廢水控制 Water usage and waste water control
- √ 使用閉路回路水冷系統冷卻爐體裝置 use closed loop water cooling systems to cool furnace devices



Company: 海光企業公司 (16)

Year Founded: 1969

Employees: 200-500

Product(s): 竹節鋼筋

Exports(?): yes

EPA penalties in the last 5 years(?): yes

EPA warning in the last 5 years(?): yes

ISO 9000 certification(?): yes

1.空污預防與減量 Air emissions prevention and abatement

√ 避免含汞原料與副料 avoid raw materials and auxiliaries that contain mercury
X 廢鋼預熱 scrap pre-heating in order to recover sensible heat from primary off gas
√ 集塵效率最佳化 optimize dust collection efficiency:
X 抽氣與封蓋系統 combination of off-gas extraction and hood systems

直接抽氣與集塵系統 direct gas extraction and doghouse systems
直接抽氣與全屋抽氣系統 direct gas extraction and total building evacuation
爐碴原地處理 on-site slag processing:
X 爐碴破碎篩選裝置有效抽氣及淨化 efficient extraction of slag crusher and screening devices with subsequent off-gas cleansing
X 以鏟車運送未處裡爐碴 transport of untreated slag by shovel loaders
√ 破碎物料輸送點之抽氣或調濕 extraction or wetting of conveyor transfer points for broken material
√ 爐碴貯存區調濕 wetting of slag storage heaps
√ 裝卸破碎爐碴使用水霧 use of water fogs when broken slag is loaded
√ 廢氣除塵袋達到低於 5mg 粉塵/Nm³ （日平均值） Waste gas de-dusting bag filter achieving less than 5mg dust/Nm3 (daily mean value)
過濾達到低於 15mg 粉塵/Nm³ （日平均值） filter achieving less than 15mg dust/Nm3 (daily mean value)
X 有機氯化合物(特別是 PCDD/F 與 PCB)減量 Minimization of organochlorine compounds, especially PCDD/F and PCB emissions
√ 排氣後燃室及驟冷 post-combustion within the off-gas duct system or in a separate post-combustion chamber with subsequent rapid quenching in order to avoid de novo synthesis
√ 驟冷 rapid quenching

2. 用水及廢水控制 Water usage and waste water control
√ 使用閉路回路水冷系統冷卻爐體裝置 use closed loop water cooling systems to cool furnace devices
X 連鑄廢水排放減量 minimize waste water discharge from continuous casting:
X 以絮凝沉降和/或過濾去除固體 remove solids by flocculation, sedimentation, and/or filtration
X 以浮除槽或其他有效裝置去除油脂 removal of oil in skimming tanks or other effective device
√ 冷卻水及真空泵水循環 recirculation of cooling water and water from vacuum generation

3. 殘碴減量 Minimization of production residues
√ 適當的收集與貯存以利特定處裡 appropriate collection and storage to facilitate a specific treatment
√ 耐火材回收與原地再用(及替代白雲石、菱鎂礦及石灰石) recovery and on-site recycling of refractory materials from the different processes for use internally (i.e. for substitution of dolomite, magnesite, and lime)
√ 集塵灰非鐵金屬(例如鋅)之場外回收 use of filter dusts for external recovery of non-ferrous metals (e.g. zinc)
X 水處理工程之連鑄垢分離與回收(例如用於燒結爐/高爐或水泥工業） separation of scale from continuous casting in the water treatment process and recovery with subsequent recycling (e.g. for use in sinter/blast furnace or cement industry)
√ 爐碴與耐火材廢料之場外再利用 external use of refractory materials and slag from EAF process where market conditions allow for it

4.降低能耗 Reduce energy consumption
√ 使用連續成型鑄造 use continuous near net shape strip casting

Company: 台灣機械公司重機廠 (17)

Year Founded: 2001

Employees: 501-1,000

Product(s): 鑄件

Exports(?): yes

EPA penalties in the last 5 years(?): yes

EPA warning in the last 5 years(?): no

ISO 9000 certification(?): yes

1.空污預防與減量 Air emissions prevention and abatement

_v_ 避免含汞原料與副料 avoid raw materials and auxiliaries that contain mercury
_x_ 廢鋼預熱 scrap pre-heating in order to recover sensible heat from primary off gas
_x_ 集塵效率最佳化 optimize dust collection efficiency:
  _x_ 抽氣與封蓋系統 combination of off-gas extraction and hood systems
  _x_ 直接抽氣與集塵系統 direct gas extraction and doghouse systems
  _v_ 直接抽氣與全屋抽氣系統 direct gas extraction and total building evacuation
_v_ 爐碴原地處理 on-site slag processing:
  _x_ 爐碴破碎篩選裝置有效抽氣及淨化 efficient extraction of slag crusher and screening devices with subsequent off-gas cleansing
  _x_ 以鏟車運送未處裡爐碴 transport of untreated slag by shovel loaders
  _x_ 破碎物料輸送點之抽氣或調濕 extraction or wetting of conveyor transfer points for broken material
  _x_ 爐碴貯存區調濕 wetting of slag storage heaps
  _x_ 裝卸破碎爐碴使用水霧 use of water fogs when broken slag is loaded
_v_ 廢氣除塵袋達到低於 5mg 粉塵/Nm³ （日平均值） Waste gas de-dusting bag filter achieving less than 5mg dust/Nm3 (daily mean value)

2. 用水及廢水控制 Water usage and waste water control

_v_ 使用閉路回路水冷系統冷卻爐體裝置 use closed loop water cooling systems to cool furnace devices

3. 殘碴減量 Minimization of production residues

_x_ 適當的收集與貯存以利特定處裡 appropriate collection and storage to facilitate a specific treatment
_x_ 耐火材回收與原地再用（及替代白雲石、菱鎂礦及石灰石） recovery and on-site recycling of refractory materials from the different processes for use internally (i.e. for substitution of dolomite, magnesite, and lime)
_x_ 集塵灰非鐵金屬（例如鋅）之場外回收 use of filter dusts for external recovery of non-ferrous metals (e.g. zinc)
_x_ 水處理工程之連鑄垢分離與回收（例如用於燒結爐/高爐或水泥工業） separation of scale from continuous casting in the water treatment process and recovery with subsequent recycling (e.g. for use in sinter/blast furnace or cement industry)
_v_ 爐碴與耐火材廢料之場外再利用 external use of refractory materials and slag from EAF process where market conditions allow for it

Company: 唐榮公司不銹鋼廠 (21)

Year Founded: 1940

Employees: 500-1,000

Product(s): stainless steel

Exports(?): (left blank)

EPA penalties in the last 5 years(?): yes

EPA warning in the last 5 years(?): no

ISO 9000 certification(?): yes

1.空污預防與減量 Air emissions prevention and abatement
- √ 避免含汞原料與副料 avoid raw materials and auxiliaries that contain mercury
- X 廢鋼預熱 scrap pre-heating in order to recover sensible heat from primary off gas
- √ 集塵效率最佳化 optimize dust collection efficiency:
  - 抽氣與封蓋系統 combination of off-gas extraction and hood systems
  - √ 直接抽氣與集塵系統 direct gas extraction and doghouse systems
  - 直接抽氣與全屋抽氣系統 direct gas extraction and total building evacuation
- √ 爐碴原地處理 on-site slag processing:
  - 爐碴破碎篩選裝置有效抽氣及淨化 efficient extraction of slag crusher and screening devices with subsequent off-gas cleansing
  - 以鏟車運送未處裡爐碴 transport of untreated slag by shovel loaders
  - 破碎物料輸送點之抽氣或調濕 extraction or wetting of conveyor transfer points for broken material
  - √ 爐碴貯存區調濕 wetting of slag storage heaps
  - 裝卸破碎爐碴使用水霧 use of water fogs when broken slag is loaded
- √ 廢氣除塵袋達到低於 5mg 粉塵/Nm^3 （日平均值） Waste gas de-dusting bag filter achieving less than 5mg dust/Nm3 (daily mean value)

2. 用水及廢水控制 Water usage and waste water control
- √ 使用閉路回路水冷系統冷卻爐體裝置 use closed loop water cooling systems to cool furnace devices
- √ 連鑄廢水排放減量 minimize waste water discharge from continuous casting:
  - √ 以絮凝沉降和/或過濾去除固體 remove solids by flocculation, sedimentation, and/or filtration
  - √ 以浮除槽或其他有效裝置去除油脂 removal of oil in skimming tanks or other effective device
- √ 冷卻水及真空泵水循環 recirculation of cooling water and water from vacuum generation

3. 殘碴減量 Minimization of production residues
- √ 適當的收集與貯存以利特定處裡 appropriate collection and storage to facilitate a specific treatment
- √ 耐火材回收與原地再用（及替代白雲石、菱鎂礦及石灰石） recovery and on-site recycling of refractory materials from the different processes for use internally (i.e. for substitution of dolomite, magnesite, and lime)
- √ 集塵灰非鐵金屬（例如鋅）之場外回收 use of filter dusts for external recovery of non-ferrous metals (e.g. zinc)
- X 水處理工程之連鑄垢分離與回收（例如用於燒結爐/高爐或水泥工業） separation of scale from continuous casting in the water treatment process and recovery with subsequent recycling (e.g. for use in sinter/blast furnace or cement industry)
- √ 爐碴與耐火材廢料之場外再利用 external use of refractory materials and slag from EAF process where market conditions allow for it

4.降低能耗 Reduce energy consumption
- √ 使用連續成型鑄造 use continuous near net shape strip casting

Company: 榮剛重工公司 (13)

Year Founded: 1993

Employees: 501-1,000

Product(s):

Exports(?): yes

EPA penalties in the last 5 years(?): yes

EPA warning in the last 5 years(?): yes

ISO 9000 certification(?): yes

Company: 中鴻鋼鐵股份有限公司

Year Founded: 1989

Employees: 1,001-1,500

Product(s): 鋼捲

Exports(?): yes

EPA penalties in the last 5 years(?): no

EPA warning in the last 5 years(?): no

ISO 9000 certification(?): yes

(EMS responses left blank)