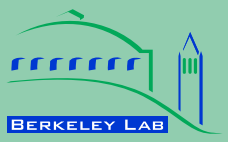

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What China can learn from international policy experiences to improve industrial energy efficiency and reduce CO_2 emissions?

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Abstract

China's industrial sector dominates the country's total energy consumption and energy efficiency in the industry sector is crucial to help China reach its energy and CO_2 emissions reduction goals. There are many energy efficiency policies in China, but the motivation and willingness of enterprises to improve energy efficiency has weakened. This report first identifies barriers that enterprises face to be self-motivated to implement energy efficiency measures. Then, this report reviews international policies and programs to improve energy efficiency and evaluates how these policies helped to address the identified barriers. Lastly, this report draws conclusions and provides recommendations to China in developing policies and programs to motivate enterprises to improve energy efficiency.

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1. Background

China's industrial sector dominates the country's total energy consumption, accounting for about 70% of total primary energy use and energy-related CO_2 emissions (NBS 2015, IPCC 1996) (Figure 1).[1] Compared with levels in most advanced economies, China's overall energy efficiency is reported to be almost 10% lower. Energy intensity (energy consumption per unit of production) for power, iron and steel, non-ferrous metals, petrochemicals, and other major industrial products is significantly higher than levels in developed countries (Current Affairs Reports, 2010).

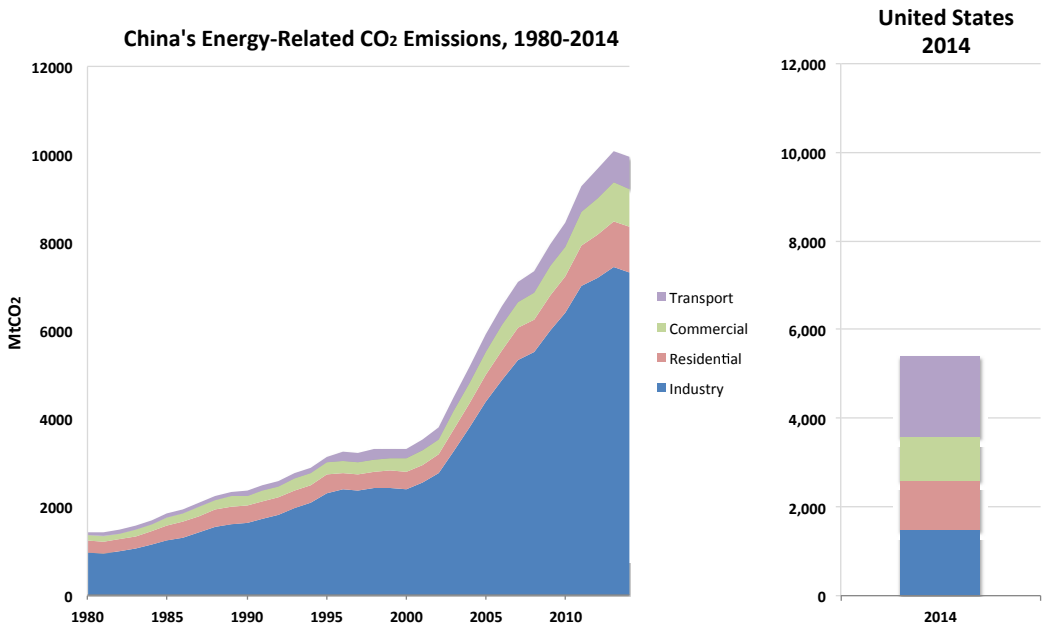

Figure 1. China's Energy-Related Carbon Dioxide Emissions and Its Comparison with the U.S., 1980–2014

Sources: NBS, China Energy Statistical Yearbooks 2015. EIA, 2015.

Improving industrial energy efficiency is crucial for China to meet its new 13th Five-Year Plan (2016-2020) goals for achieving energy intensity reduction by 15% and reducing particulate matter ($PM_{2.5}$) emission in 30% of Chinese cities to below the required level of the national standards, and its Paris Agreement pledges of achieving a CO_2 emissions peak around 2030 or earlier, of increasing the share of non-fossil fuels in primary energy consumption to around 20% by 2030, and of reducing its carbon intensity by 60–65% in 2030 over 2005 levels.

[1] CO_2 emissions were estimated based on reported energy data (NBS, 2015) multiplied by Intergovernmental Panel on Climate Change (IPCC) default emission factors.

China has implemented a series of policies and programs to improve industrial energy efficiency. The Top-10,000 program introduced during the 12th Five-Year Plan (2011-2015) as an expansion and continuation of the Top-1000 program during the 11th Five-Year Plan is the most comprehensive national program in the industrial sector to improve energy efficiency. Total energy consumption of covered enterprises accounted for 60% of national energy use with 5.5 billion tons of carbon dioxide ($GtCO_2$) emissions. Even though accumulated energy savings of the Top-10,000 Program has surpassed the program target (NDRC, 2015), the willingness and self-motivation of companies to invest in energy efficiency improvements have weakened (Yu, 2016).

In order to help China achieve its ambitious energy and carbon goals given the decreasing motivation in industrial energy efficiency in enterprises, it is crucial to explore mechanisms and policies to incentivize enterprises to improve energy efficiency in a more proactive way. There are several review papers on energy efficiency policies in China and around the globe in the industry sector (Zhou, et al. 2010, Lo, 2014, Abdekaziz, 2010), however, they did not analyze how policies could help to solve existing problems that industrial companies face and why this kind of policies are necessary. In this report, we review the common barriers that industrial companies encounter which impede them from applying energy efficiency measures, identify issues that China's industrial sector faces in improving energy efficiency, review international policies and programs on energy efficiency policies for overcoming these barriers, and provide recommendations to China.

1.1 Introduction to the Top-10,000 Enterprises Program

In 2011, China's National Development and Reform Commission (NDRC) initiated the Top-10,000 Energy Efficiency and Low Carbon Action Program ("Top-10,000 Program") for industries, transportation, businesses, hotels, schools, and other key energy consuming enterprises that consume more than 10,000 tons of coal equivalent (tce)[2] of annual primary energy and some key energy consumption enterprises that consume more than 5000 tce of annual primary energy. In 2010, a total of 16,078 enterprises were included in the Top-10,000 Program, with a total primary energy consumption of about 2.1 billion tce, accounting for 60% of national energy use, and emitting 5.5 billion tons of carbon dioxide ($GtCO_2$).

The Top-10,000 Program enterprises are concentrated in Shandong, Jiangsu, Hebei, Henan, Guangdong, Liaoning, Shanxi, Inner Mongolia, Sichuan, and Zhejiang provinces. In these provinces, enterprises in the Top-10,000 Program consume about 1.3 billion tce, accounting for more than 60% of total energy consumption of all enterprises under the program and over 35% of national energy use. Their CO_2 emissions are around 3.3 $GtCO_2$.

[2] tce is the standard unit for energy used in China and 1 tce is equivalent to 29.27 Gigajoules (GJ).

To introduce a market-based mechanism to promote energy efficiency in key energy consuming enterprises, NDRC established carbon trading pilots in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen beginning in November 2011. By June 2014, all 7 pilots had started. By the end of March 2015, the total transaction volume of the 7 pilots was about 20 million tons of CO_2, with a total transaction amount of 1.3 billion yuan. Top 10,000 Program plants participate in all seven carbon markets, but Guangdong province is the only area where Top-10,000 Program enterprises dominate the carbon market.

Energy savings trading programs targeting key energy consuming enterprises or energy efficiency retrofit projects have also been initiated in Shandong, Fujian, and Jiangsu provinces. Two areas with a large number of Top-10,000 enterprises - Shandong and Jiangsu provinces - participate in these programs.

The 2015 evaluation of the Top-10,000 Program by NDRC included the current 13,328 enterprises (2750 enterprises had been restructured, shut down, moved away, or eliminated since 2010). By the end of 2014, about 82% of the evaluated enterprises achieved or exceeded their energy saving targets, 11% basically achieved their targets, while about 7% failed to achieve their targets. From 2011 to 2014, the accumulated energy savings of the Top-10,000 Program was 309 million tce (Mtce), or 121% of the total program target for the full 12th Five-Year Plan (FYP) period (NDRC, 2015). However, the willingness and self-motivation of companies to invest in energy efficiency improvements have been getting weaker and weaker. There are both macroeconomic factors and government program design reasons that have contributed to the current situation: 1) China's economic slow-down and the decrease in demand for high energy-intensive products, which has reduced the pressure for reaching energy efficiency targets in companies; 2) a large decline in coal and oil prices which has reduced energy costs in companies, making energy efficiency an area of lower priority in the eyes of high-level company leaders; 3) many monetary incentive policies during the 11th FYP, such as energy efficiency retrofits rewards and energy performance contracting awards have ended; and 4) command-and-control and top-down types of policies on allocating and evaluating energy saving targets are viewed as limiting companies from improving energy efficiency proactively and innovatively.

1.2 Challenges to Realize Energy Efficiency

To better understand the more specific challenges Top 10,000 enterprises face to improve energy efficiency, the Energy Research Institute (ERI) and the Lawrence Berkeley National Laboratory (LBNL) research team conducted surveys to interview local policy-makers and companies in four provinces – Hebei, Hubei, Sichuan and Jiangsu - which represent west, central and east China. Questionnaires from 1307 enterprises were collected. The enterprises' responses revealed some common issues, including a lack of funding/financing,

a lack of technical expertise and personnel, a lack of practical information on technologies and products, and difficulties using energy performance contracting (EPC).

These issues are not uncommon, as they have been observed in a variety of studies that showed much of the cost-effective energy-efficiency potential is not captured around the world due to obstacles and barriers that hinder the adoption of cost-effective energy-efficient technologies (Brown 2001; DeCanio, 1993; Golove and Eto, 1996; CBI, 2015; SEE Action 2014). Studies in the US and the UK have identified the following issues: a lack of broad-level awareness of the benefits of energy efficiency (CBI, 2015; SEE Action, 2014), a lack of necessary skills to both build the business cases for energy efficiency investment and to implement energy efficiency measures within businesses (CBI, 2015; SEE Action 2014; Brown 2001; Golove and Eto 1996), a lack of appropriate incentives to encourage energy efficiency investments, and difficulties in understanding and accessing finance (CBI, 2015; SEE Action, 2014; Brown, 2001).

These common barriers can be addressed by government interventions through targeted energy efficiency policies and programs. For example, to increase the awareness of energy efficiency within businesses, the cost of energy or carbon can be increased, and information on benefits of improving energy efficiency can be provided to businesses; to fill in the skills gap, technical assistance or information sharing can be provided; to incentivize energy efficiency investment, information can be provided, and grants or favorable tax treatment can be provided to reduce investment risks, etc. Table 1 lists the obstacles and potential policies or programs that could address these obstacles.

In this report, we summarize and evaluate international experiences on the policies and programs in Table 1 and make policy recommendations to China to design a program to incentivize enterprises to achieve energy efficiency improvement.

Table 1. Barriers for Energy Efficiency and Potential Policies and Programs to Address Them[3]

[3] Note: "Awareness" stands for awareness of energy efficiency opportunities in enterprises. If a policy or program can address this issue, it means the policy or program could help enterprises be aware of potential energy efficiency opportunities and be willing to consider energy efficiency improvement in their managerial decisions.
"Information" stands for information gaps for enterprises. Such gaps include information on available energy efficiency measures, technologies or products, the economics of these measures/technologies/products, financial benefits and investment information of implementing energy efficiency measures. If a policy or program can address this issue, it means the policy or program could provide the information above to help enterprises make energy efficiency improvement decisions.
"Technical" stands for technical gaps in enterprises. Enterprises either lack the technical staff to identify energy efficiency opportunities and implement energy efficiency measures, or lack to affordable access to technical support in these areas. If a policy or program could address this issue, then the policy or program could either provide training to equip enterprises with the ability to conduct such activities, or directly provide support or conduct these activities, or facilitate EPC or help the engagement of ESCOs.

Program	Awareness	Information	Technical	Finance
Energy and carbon trading	X	X	X	X
Voluntary agreements	X	X	X	X
Information on technology costs and savings		X		
Energy audits		X	X	
Benchmarking			X	
Enterprises rating			X	
Economic benefits calculations		X		
Technology promotion list		X		X
Green bank			X	X
Interest-free loans				X
Public-private partnerships			X	X
Tax incentives				X
Third party participation		X	X	

2. Overarching Programs to Incentivize Energy Savings and Emissions Reduction

2.1 Energy and Carbon Trading

Carbon emissions trading schemes have been adopted in a number of countries as a means to price carbon, reduce CO_2 emissions, and save energy. Emissions trading schemes are used to incentivize enterprises to invest in energy efficiency and emissions reduction projects through raising the cost of using energy and generating CO_2 emissions by charging enterprises a price per ton of CO_2 emitted (Aflaki, et al. 2012; Altmann, et al. 2013). In this section, we review policies and programs under three emissions trading schemes and discuss how these policies and programs could incentivize energy efficiency. Energy trading schemes are similar, but instead of trading carbon allowances, energy trading schemes use energy savings certificates. We review the white certificate scheme in Europe and the Perform, Achieve, Trade scheme in India.

2.1.1 United Kingdom (UK) Climate Change Program - UK Emissions Trading Scheme (ETS), Climate Change Levy (CCL), and Climate Change Agreements (CCAs)

Program Overview. The UK Climate Change Program was established in 2000 to meet both the country's Kyoto Protocol commitment of a 12.5% reduction in GHG emissions by 2008-2012 relative to 1990 and the domestic goal of a 20% CO_2 emissions reduction relative to 1990 by 2010 (DEFRA, 2006). In November 2000, UK implemented the Climate Change Program legislative package, which deployed three interlinked instruments: the UK

"Finance" stands for financial difficulties of implementing energy efficiency measures, including lack of investment incentives for energy efficiency improvement, difficulties in accessing finance, etc. If a policy or program can address this issue, it means the policy or program could reduce these financial risks or difficulties.

emissions trading scheme (ETS), the Climate Change Levy (CCL), which is a tax on fossil fuel users, and the Climate Change Agreements (CCAs) which set energy or emissions targets and provided rebates of the CCL to enterprises that achieved their targets (UK Gov, 2014; IIP, 2015a).

The UK Emissions Trading Scheme (ETS). The UK ETS was launched in 2002 as the first carbon trading system (IETA 2013a). In 2007, the mandatory European Union Emissions Trading System (EU ETS) replaced the UK ETS. During 2005 and 2006, the UK ETS and the EU ETS were both effective, while the EU ETS took precedence as the EU ETS was mandatory, but the UK ETS was voluntary. Originally, there were two types of participants in the UK ETS – direct participants and agreement participants that are covered by CCAs. In 2007, direct participants exited the UK ETS, making the focus on sectors covered by CCAs thereafter (IETA, 2013a).

UK Climate Change Agreements (CCAs). Under the CCAs, UK's Environment Agency and industry enter into voluntary agreements to reduce energy consumption and CO_2 emissions. In return, companies that meet their agreed-upon target can receive a discount on the CCL. The discount was initially set to be 80% from the CCL and was later revised to 90% on electricity bills and 65% on other fuels. Companies that entered into a CCA and surpassed their target could trade on the carbon emissions trading market, initially through the UK ETS (IETA, 2013a; UK Gov, 2014) and later through the EU ETS.

UK Climate Change Levy (CCL). The CCL is a key element of the UK Climate Change Program. It is a tax on the use of energy (natural gas, coal, liquefied petroleum gas, and electricity) applied to industry, commerce, agriculture, and the public sector. The revenues from the levy are returned to the taxed sectors through a reduction in the rate of employer's National Insurance Contributions and used to fund programs that provide financial incentives for adoption of energy efficiency and renewable energy (UK Gov, 2016).

Interactions of UK ETS, CCA, and CCL. 6,000 companies that had CCAs also participated in the UK ETS. CCA companies that exceeded their targets and had excess carbon allowances were allowed to trade with companies that did not meet their targets through the UK ETS (Smith and Swierzbinski, 2007). The carbon allowances could also be banked for future periods. CCA companies that did not meet their targets could purchase carbon allowances. If a company did not enter into a CCA or if a company within an agreement did not reach its target, then the full 100% of the energy tax had to be paid (NAO, 2007).

How the UK Climate Change Program Incentivizes Energy Efficiency

The CCL raises awareness of energy efficiency and influences managerial decisions. It is important to influence top decision-makers at a company because board awareness is found

vital to instigating energy efficiency improvements (CBI, 2013). Three factors are important to a company's decision to invest in energy efficiency projects: 1) financial elements of the projects and the company, such as payback periods and return on investment (ROI); 2) obligations on environmental compliance for the company; and 3) knowledge of energy savings opportunities within the company (Reinaud and Goldberg, 2011; Elliott, 2007). The CCL was designed specifically to promote energy efficiency by taxing businesses' use of energy. Because of the increased cost of using energy, business started to make energy efficiency improvements (NAO, 2007)

Target-setting process for CCAs helps enterprises realize unknown energy efficiency opportunities. The process for setting the CCA targets began with information-gathering on the part of the government. The government obtained information regarding energy efficiency potential in energy-intensive industries through the Energy Efficiency Best Practices Program, which produced good practice guides and case studies, new practice case studies, and information on future practices, as well as through a report prepared by Energy Technology Support Unit (ETSU) (now AEA Energy & Environment) on projections of industrial sector CO_2 emissions under a business-as-usual scenario as well as two scenarios that included all cost-effective and all technically-possible technologies (ETSU, 1999). Then, for the ten largest energy-consuming sectors, individual companies made estimates of what energy efficiency improvements they could make based on an assessment of their potential and provided this information to their trade associations.

Once this information was gathered, negotiations took place within each sector. The sector offered a target for the whole sector to the government. Negotiation then moved the process forward, with government often requiring the industry sector to improve their offer to a more challenging level, based on information on cost-effective processes and general standards of energy management in the sector (Price et al., 2005).

When negotiating the targets, most companies believed that they were already energy-efficient, but when they actually undertook energy management because of the CCA targets, companies saved more than they thought that they could, especially through improved energy management (Pender, 2004). As a result, sectors did better than expected because industry underestimated what they could achieve via energy efficiency. The CCA negotiating process made industrial managers aware of the extent of existing cost-effective opportunities for industrial energy-efficiency improvements, which they may not have known until the studies leading up to the negotiation process were undertaken (Ekins and Etheridge, 2006; Barker, et al. 2007; NAO, 2007).

Participating in CCAs brings benefits such as financial incentives and technical assistance in energy efficiency. Benefits to companies that participate in the CCAs include the services

of the Carbon Trust, the UK Enhanced Capital Allowance Scheme, the ability to participate in the UK's domestic emissions trading scheme, and a "light touch" on energy efficiency regulation, all of which provided financial incentives and technical assistance to encourage investment in energy-efficient industrial equipment and processes.

The UK's Carbon Trust provides information and technical expertise to the companies and also provides interest-free loans to small- and medium-sized enterprises. The Carbon Trust is an independent entity that assists businesses and the public sector to reduce carbon emissions. The Carbon Trust, which is funded from the proceeds of the CCL, identifies CO_2 emissions reduction opportunities, provides resources and tools, provides interest-free loans to small- and medium-sized enterprises, funds a local authority energy financing scheme, promotes the government's Enhanced Capital Allowance Scheme, and has a venture capital team that invests in early-stage carbon reduction technologies as well as management teams that can deliver low carbon technologies (Carbon Trust, 2016).

The Enhanced Capital Allowances (ECA) encourage firms to make energy-saving and low-carbon investments by providing informational benefits and tax relief. The UK's ECA Scheme allows a business to claim 100% first-year tax relief on their spending on qualifying energy-saving technologies specified in the "Energy Technology List" on their income or corporation tax return. Businesses can write off the entire capital cost of their investments in energy-saving technologies against their taxable profits for the year during which they make the investment (HM Revenue & Customs, 2008). The UK government published specific energy-saving or energy-efficiency criteria for each type of technology. The technology must meet the specified criteria to be eligible on the Energy Technology List. The Carbon Trust manages the list on behalf of the UK government. The list and criteria are available on the UK government website[4]. The technologies that currently appear on the 2015 Energy Technology List are: air-to-air energy recovery, automatic monitoring and targeting (AMT), boilers, combined heat and power (CHP), compressed air equipment, heat pumps, heating, ventilation and air conditioning (HVAC), high speed hand air dryers, lighting, motors and drives, pipework insulation, refrigeration, solar thermal systems, uninterruptible power supplies, warm air and radiant heaters, and waste heat to electricity conversion equipment (UK Gov, 2015c).

CCA companies are provided a "Light Touch" on energy efficiency regulation which means that facilities that meet their CCA targets are deemed to have met the European Union Integrated Pollution Prevention and Control (IPPC) permit conditions. As such, these

[4]The Energy Technology List and Energy Technology Criteria List can be found at the UK government website. Energy Technology List (ETL): https://www.gov.uk/guidance/energy-technology-list; Energy Technology Criteria List (ETCL): information by categories: https://www.gov.uk/government/collections/energy-technology-criteria-list-etcl-information-by-categories#automatic-monitoring-and-targeting-equipment

facilities need only to report basic energy use data and an energy plan to comply with the EU Directive.

Evaluation has shown that the UK's Climate Change Program has been effective.
Table 2 shows that during the first target period (2001-2002) of the UK CCA program, total realized CO_2 emissions reductions were nearly three times higher than the target for that period (Future Energy Solutions, AEA Technology, 2004). Industry realized total CO_2 reductions that were more than double the target set by the government during the second target period and that were significantly above the target during the third, fourth, and fifth target periods (Future Energy Solutions, AEA Technology, 2005; DEFRA, 2007; AEA Technology, 2011).

Table 2. Results of the UK Climate Change Agreements: Periods 1-5

Absolute Savings from Baseline	Actual ($MtCO_2$/year)	Target ($MtCO_2$/year)	Actual minus Target ($MtCO_2$/year)
Target Period 1 (2001-2002)	16.4	6.0	10.4
Target Period 2 (2003-2004)	14.4	5.5	8.9
Target Period 3 (2005-2006)	16.4	9.1	7.3
Target Period 4 (2007-2008)	20.3	11.1	9.2
Target Period 5 (2009-2010)	28.5	18.0	10.5

Source: AEA Energy & Environment, 2011.

Many evaluation reports of the program found that the Climate Change Program and bundling of CCL and CCAs have raised awareness of energy efficiency potential within the participating sectors to enable businesses to achieve energy efficiency improvement (NAO, 2007) and have done more to increase awareness of energy efficiency across industry than any other government scheme" (UK Steel, 2007). The program have also "reinforced business and competitive benefits through lower energy bills" (Food and Drink Federation, 2007), and provided "positive macroeconomic effects in economic terms, with small increases in GDP and employment, and negligible changes in general inflation" (Barker et al., 2007).

2.1.2 EU Emissions Trading Scheme (EU ETS)

Program Overview. The European Union (EU) Emissions Trading Scheme (ETS) was launched in 2005 and has been extended over three successive phases: Phase I (2005–2007, often called the "pilot phase"); Phase II (2008–2012); and Phase III (2013–2020) (Brown et al., 2012). The system covers around 45% of total greenhouse gas emissions from the 28 EU countries, including CO_2 emissions from power plants, energy-intensive industry sectors and commercial airlines, nitrous oxide emissions from the production of certain acids, and emissions of perfluorocarbons from aluminum production (European Commission, 2015a).

How EU ETS Incentivizes Energy Efficiency

Pilot phase and MRV helps build an emissions inventory and fill information gaps. The EU ETS went through a series of adjustments during its different phases. In Phase I (pilot phase), almost all allowances were allocated for free. In Phase II, free allocation was reduced by 10% and auctions were introduced. In Phase III, all allowances for the power sector are auctioned and the share of free allowances for industries declines from 80% in 2013 to 30% in 2020. Because of a lack of reliable emissions data before Phase I and decline in emissions due to the global economic crisis during Phase II, the caps set for these two phases exceeded actual demand, which resulted in the EU ETS having little impact on emissions. However, rigorous monitoring and increased awareness, together with a positive carbon price, generated some emissions reductions and also generated verified annual emissions to fill the information gap and created a solid basis for setting national caps for the following phases (European Commission, 2015b; Laing, et al. 2013).

Benchmarking used for allowance allocation. In the covered energy-intensive industry and aviation sectors, most allowances are allocated for free and the remaining allowances are auctioned. Energy-intensive industry received 80% of its allowances for free in 2013; with free allowances to decrease annually to 30% in 2020. In the energy-intensive industries, free allowances are allocated based on benchmarks, which are the arithmetic averages of performance of the 10% most energy efficient factories in 2007 and 2008 (European Commission, 2011). For a facility, the allowance allocation is the benchmark value for the product it produces multiplied by its historic production.

The benchmarks were developed for products, instead of inputs, so that the GHG emissions reductions and energy efficiency improvement can be maximized throughout each production process. The European Commission provides the complete list for product benchmarks and system boundaries, which is public available at the European Commission website (European Commission, 2011). To develop these benchmarks, the European Commission consulted with industry as well as different stakeholders of the covered sectors and sub-sectors, including industry associations, member states, and publicly and commercially available sources (European Commission, 2013).

Benchmarking encourages economic efficiency in the allowance market and provide the best incentives to minimize compliance costs (Harrison and Radov, 2002). Benchmarking identifies the most energy-efficient and low-emission installations across the EU. For existing installations, benchmarking provides a greater incentive for companies to replace old and inefficient installations (Schleich, et al. 2009). Analysis on the rules of the EU ETS shows that incentives for investing in energy efficiency for enterprises are higher as the application of benchmarking to new and existing installations increased and the share of allowances allocated for free was reduced (Schleich, et al. 2009).

Emissions trading process affects managerial decisions related to energy efficiency and carbon-intensive investments. The EU ETS has been shown to affect investment decisions, though in limited ways: 1) there have been some small-scale energy efficiency related investments; 2) it helped companies to stop major carbon intensive investments and to make decisions with longer-term strategic thinking; 3) it helped climate change to gain attention in company boardrooms (Laing, et al. 2013).

2.1.3 California: Cap-and-Trade Scheme (AB32)

Program Overview. Under California's Global Warming Solutions Act (AB32), introduced by Governor Schwarzenegger in 2006, California set a GHG reductions target to achieve 1990 level emissions by 2020. A cap-and-trade scheme was implemented starting in 2013 as a measure to achieve the AB32 goal.

The California cap-and-trade program has three compliance periods: 2013-2014, 2015-2017, and 2018-2020, respectively. The first compliance period covers the industrial sector and first deliverers of electricity (in-state and imported), which is about 35% of California's total GHG emissions (World Bank, n.d.). The second and third compliance periods expand the coverage to distributors of transportation fuels, natural gas, and other fuels, representing a total of 85% of California's total GHG emissions (World Bank, n.d.).

Within each compliance period, there is a descending cap for each year. The cap set in 2013 was about 2% below the emissions level forecast for 2012. This cap then declines about 2% in 2014 and about 3% annually from 2015 to 2020 (CARB, 2011a). The total cap is 394.5 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) in 2015 (EDF, 2015). The carbon prices that will result from AB32 implementation and expansion are expected to drive approximately 20% of the reductions required in the covered sectors to achieve AB32's statewide 2020 goals (CARB, 2011a).

California's Industrial Sector and the Cap-and-Trade Program. Based on the California Air Resources Board (CARB)'s newest 2020 business-as-usual (BAU) emissions projection, California's industrial sector accounts for about 20% of total GHG emissions (CARB, 2014). In the industrial sector, the cap-and-trade program covers operators of industrial facilities that exceed annual emissions of 25,000 $MtCO_2e$ based on their mandatory GHG emissions reporting. Facilities that do not exceed the threshold can voluntarily opt into the cap and trade program as opt-in covered entities. Covered industrial subsectors include: 1) cement production; 2) cogeneration; 3) glass production; 4) hydrogen production; 5) iron and steel production; 6) lead production; 7) lime manufacturing; 8) nitric acid production; 9) petroleum and natural gas systems; 10) petroleum refining; 11) pulp and paper manufacturing; 12) self-generation of electricity; and 13) stationary combustion.

How CA ETS Incentivizes Energy Efficiency

Energy efficiency assessments help to identify energy efficiency opportunities. Effective July 16, 2011, the Energy Efficiency and Co-Benefit Assessment of Large Industrial Facilities (EEA Regulation) requires the largest industrial sources in California to conduct a one-time assessment of fuel and energy consumption, as well as emissions of GHGs, criteria pollutants, and toxic air contaminants. Affected facilities were also required to identify potential improvements in equipment, processes, or systems that could result in energy savings. All California facilities with 2009 GHG emissions equal to or greater than 0.5 $MtCO_2e$ are subject to the Regulation. Also subject to the requirements are cement plants and transportation-fuel refineries that emitted at least 0.25 $MtCO_2e$ in 2009.

Facilities in all four of the large industrial sectors covered by cap and trade in California (refineries, cement, hydrogen, and oil and gas production/mineral production) conducted these one-time assessments to help determine potential emissions reduction opportunities. Eight cement manufacturing facilities, twelve refineries, three hydrogen facilities, five oil and gas production facilities and one mineral processing facility submitted EEA Reports to CARB. CARB summarized the reports from each facility by sector and developed public reports. CARB reviewed all submitted EEA reports to ensure information met the EEA regulation data requirements and contacted facility staff if clarification or additional information was required. There is also a third-party review process. CARB contracted with Industrial Assessment Center at San Francisco State University (SFSU) for the third-party review. The third party reviewers reviewed nine randomly selected reports and contacted facility staff directly to obtain supplemental/clarifying information.

As an example, the assessment of the 12 refineries in California identified 401 energy efficiency improvement projects that were completed, ongoing, scheduled, or under consideration, which would reduce GHG emissions from these 12 facilities by about 9% annually, or 2.78 $MMTCO_2e$ (Kiung and Morehouse, 2015; CARB, 2013a). The assessment of the 8 cement factories in California identified 79 energy efficiency improvement projects, which would reduce GHG emissions by 0.68 $MMTCO_2e$ annually (CARB, 2013b). Assessments on the 5 oil and gas production facilities and one mineral processing facility identified over 140 energy efficiency improvement projects with an expected emissions reduction of 1.6 $MMTCO_2e$ per year (CARB, 2014).

The CA ETS has influenced abatement and investment decisions at the managerial level. The Climate Policy Initiative (CPI) conducted a study evaluating the California ETS and analyzed the barriers and opportunities for emissions reductions in the cement sector. The report found that “the carbon price signal is making a difference in how firms approach abatement decisions”. Companies that participated in the study also confirmed that “they are currently

factoring in an expected carbon price into their investment decisions and emissions reduction strategies" (Kiung and Morehouse, 2015; CPI, 2014).

Auction proceeds can help California move towards an energy efficient, low-carbon economy. The CA ETS uses a combination of free allocation using benchmarking and auctions for allowance allocation. Covered industry entities can get free allowances based on an industry assistance factor, which indicates the level of leakage risk – high, medium or low[5]. Entities under the high leakage category receive 100% free allowances during the three compliance periods. Entities under the medium and low leakage categories receive 100% free allowances during the first and the second period and 75% and 50% free allowances during the third period, respectively.

Beyond free allowances, for other allowances issued under the cap-and-trade program, the entities participate in the quarterly State-run auctions to buy additional allowances. California has held 13 quarterly allowance auctions by the end of 2015, raising a total of $3527.3 million, which all goes to the Greenhouse Gas Reduction Fund (GGRF) (CARB, 2015c). Auction proceeds will be reinvested into a variety of activities, including energy efficiency improvements in affordable housing, sustainable communities, public transit, high-speed rail, public buildings, etc., to reduce climate pollution and benefit the economies, health, and environment of California's communities (Kiung and Morehouse, 2015).

2.1.4 White Certificates for Energy Suppliers or Distributors

Program Overview. A White certificate system is a combination of an obligation and a trading system, focused on energy suppliers or distributors. White certificates (e.g., 1 White Certificate = 1 ton of oil equivalent of energy saving) are documents certifying that a certain reduction of energy consumption has been attained (Brogi and D'Adamo, 2007). Government bodies set specific mandatory energy saving targets for energy suppliers or distributors. Under these energy-saving obligations, energy suppliers or distributors must fulfil these requirements by implementing energy efficiency measures among their clients (i.e. end-use sectors) within a specific time frame. There are three ways to fulfill their targets: 1) implement energy efficiency measures in end-use sectors; 2) make agreements with other companies to implement projects that are carried out with the help of third-party organizations, such as manufacturers of energy-efficient products, installers, or ESCOs; 3) purchase white certificates from the market (Steuwer, 2012). Energy suppliers or

[5] The leakage risk is the risk that the entities within the industry may move out of the state due to competitive disadvantage because of the cap-and-trade program, which causes the leakage and the reduction in emissions of GHGs within the state is offset by an increase in emissions of GHGs outside the state. There are three categories of potential leakage: 1) high leakage, which includes oil and gas extraction, mining, paper mills, and chemical, glass, iron and steel, and cement manufacturing; 2) medium leakage, which includes food manufacturing, petroleum refineries, rolled steel shape manufacturing; and 3) low leakage, which includes pharmaceutical manufacturing and aircraft manufacturing. Table 8-1 of the CARB Regulation (CARB, 2011b) provides a complete list of specific sectors and their leakage risk classification.

distributors that surpass their targets can sell their unused energy efficiency equivalents in the form of White Certificates to suppliers/distributors who have implemented fewer measures than required to meet their targets (Secretariat, Energy Charter 2010; Steuwer, 2012).

The White Certificates system has been implemented in many European countries, including Great Britain (2002), Italy (2005), France and Denmark (2006), and Poland (2011) (Labanca 2008; ABB, 2013). The designs of the White Certificate schemes across different countries are very different. For example, the UK and France have chosen to impose the obligation on suppliers, while in Italy, the obligation is on distributors; France and Italy allow non-obliged parties to promote energy savings and sell them to obliged parties, while UK doesn't; Italy uses primary energy as the metric for energy savings of the obligation, while the UK and France use final energy (Bertoldi, 2011; Giraudet, et al. 2012). But under all white certificate schemes in the EU, obliged parties have met or exceeded their energy-saving targets (Bertoldi, 2011; Aaltonen, 2011).

White Certificates provide an accounting tool to represent the amount of energy savings and a trading mechanism. As an example, the Italian White Certificates system was initiated in 2005 to help meet compliance with the Kyoto protocol of reducing emissions by 6.5% from 2008 to 2012 compared to 1990 level. The Italian government set quantitative annual targets for 30 electricity and gas distribution companies that have more than 100,000 customers (Brogi and D'Adamo, 2007; Dyhr-Mikkelsen, et al. 2007). These companies must surrender a certain amount of White Certificates to fulfill their targets. Companies can promote energy efficiency actions for their costumers or buy White Certificates on the trading market. White certificates (1 White Certificate = 1 ton of equivalent oil per year (toe/year) of absolute saving of primary energy) record the amount of primary energy that has been saved and at the end of each compliance period, each company will submit White Certificates to the Authority for Electricity and Gas. The trading component of the Italian White Certificates system allows both distribution companies and ESCOs to trade. Since ESCOs don't have any obligation or targets with the government, they can implement energy efficiency actions for any companies and sell their White Certificate to distribution companies to make a profit (Brogi and D'Adamo, 2007).

White Certificate System has the potential to stimulate the ESCO industry. To fulfill the White Certificate energy savings obligation, energy providers or distributors can enlist ESCOs to help their clients to install and implement energy efficiency measures. Bringing ESCOs, which have unique experience and expertise with energy efficiency projects and technologies, into the scheme provides the opportunity not only for enterprises to have better access to energy efficiency improvement services, but also for the ESCOs industry to grow.

In addition, in Italy, trading programs open markets to third parties, such as ESCOs, which may stimulate the growth and development of the ESCO industry (Bertoldi et al. 2006). ESCOs can help distributors implement energy efficiency projects and are also allowed to sell the certificate on the market (Bertoldi, 2011; Aaltonen, 2011). By doing so, the White Certificates scheme can see greater overall savings at a lower overall compliance cost, by virtue of empowering these third-parties to derive value from the White Certificates (Friedman et al. 2009). Active trading and a growth of ESCO companies were seen in the case of Italy (Bertoldi, 2011; Aaltonen, 2011). A significant share (80% in the period 2005-2008) of actions were implemented by ESCO companies and the White Certificate scheme gradually promoted the entry of new companies providing energy efficiency services and stimulated the development of the ESCOs industry (Aaltonen, 2011). An evaluation of the Italy White Certificate scheme found that the scheme helped to promote the growth of energy efficiency actors better than stimulating energy efficiency project implementation (Santo, et al. 2011).

2.1.5 India Perform, Achieve, Trade (PAT) Scheme for Energy-intensive Industries

Program Overview. India's Perform, Achieve, Trade (PAT) program is a market-based, energy efficiency trading scheme that aims to improve energy efficiency in energy-intensive industries. The Indian Government announced this scheme in 2008 under its National Mission on Enhanced Energy Efficiency (NMEEE) in the National Action Plan on Climate Change (NAPCC). The PAT Scheme is being implemented in three phases; the first phase ran from 2012-2015. This phase covered 478 facilities ("Designated Consumers"), using about 165 Mtoe per year in total, from eight energy-intensive sectors: aluminum, cement, chor-alkali, fertilizer, iron and steel, pulp and paper, textiles and thermal power plants (Kumar, n.d.). Covered facilities accounts for roughly 45% of India's energy consumption and 60% of India's total GHG emissions (CCAP, n.d.; IETA, 2015). PAT targets energy consumption reductions of 6.6 Mtoe (9.42 Mtce) (IETA, 2015).

The Ministry of Power's Bureau of Energy Efficiency (BEE) is responsible for setting mandatory, specific targets for energy consumption for larger, energy-intensive facilities (CDKN, 2013; IIP, 2015b). BEE sets energy efficiency targets for each Designated Consumer (DC) by calculating their baseline production, baseline energy consumption, and analyzing their potential for energy efficiency improvement. The government will set stricter target (percentage of reduction relative to baseline energy consumption) for historically less-efficient DCs than more-efficient ones. DCs report their energy efficiency efforts and progress to achieve their targets during the compliance period. If DCs save more energy than their targets, they will receive energy savings certificates (1 certificate=1 Mtoe), equaling to the amount of energy they have saved minus the amount of targeted savings.

These certificates can be traded on two power exchanges, and a platform developed by BEE specifically for the trading of energy saving certificates (IETA, 2015; CCAP, n.d.).

How PAT may Incentivize Energy Efficiency

The PAT scheme is the first cap-and-trade program for energy efficiency in developing countries (IETA, 2013b). In theory, the scheme should enable industrial firms to continue expanding their activities, as long as they operate in an environmentally conscious manner. It is estimated that the industrial units covered by the PAT scheme could save more than USD 1 billion by fiscal year 2014-2015 if they meet their specific energy consumption targets (CCAP, n.d.).

The scheme has also created an institutional structure to enable online data submission, annual audits and verification by designated auditors. It also helps enhance capacity-building in enforcing policies, collecting data, conducting monitoring and verification, and assessing compliance and levying penalties, which are all prerequisites for successfully implementing the scheme (CDKN, 2013).

There are currently limited empirical studies assessing the effectiveness of the PAT scheme. A study mapping 48 Designated Consumers (DCs) across cement (24), fertilizer (3), Textile (3), pulp and paper (4), aluminum (5), chor-alkali (1), iron and steel (5), and thermal (3) sectors found that during Phase I, projects focused on retrofit or repair and maintenance in most sectors (AEEE, 2015). Few sectors focused on technology installation projects or adopted Best Available Technologies (BAT) (AEEE, 2015). Process modification and instrumentation related projects were also very low share of the projects (AEEE, 2015). The study also found that there is a need for catalyzing financing, such as through low interest loans, green bonds and ESCO models (AEEE, 2015).

2.2 Voluntary Agreements

Agreements to meet specific energy-use or energy efficiency-targets are used in the industrial sector in many countries around the world (Bertoldi, 1999; Chidiak, 1999; Hansen and Larsen, 1999; Mazurek and Lehman, 1999; Newman, 1998; Paton, 2002). Such agreements can be viewed as a tool for developing a long-term strategic plan for increasing industrial energy efficiency that fully engages not only the engineers and management at industrial facilities, but also includes government, industry associations, financial institutions, and others. An agreement or target can be formulated in various ways. Two common methods are those based on specified energy-efficiency (or energy intensity) improvement targets and those based on absolute energy use or greenhouse gas emissions reduction commitments. Either an individual company or an industrial subsector, as represented by a party such as an industry association, can enter into such agreements. (Price, et al. 2003)

Voluntary agreements on energy savings often exist with the ETS. As a result, in many countries, including Germany, Belgium, Finland, Netherland, and the UK, voluntary agreements on energy savings also apply to participating enterprises in the EU ETS. Generally, under a voluntary agreement, participants negotiate a target with the government and by achieving the target, participants can get a variety of support and benefits from the government including technical assistance for energy efficiency, subsidies for energy audits and energy efficiency investments, tax relief or reduction, etc. There are also countries that use voluntary agreements with non-ETS participants and the mechanism and benefits are similar.

How Voluntary Agreements Incentivize Energy Efficiency

The key elements of voluntary agreement programs are the assessment of the energy-efficiency potential of the participants as well as target-setting through a negotiated process with all parties. The targeting setting process enables enterprises to better understand their energy efficiency opportunities. In addition, voluntary agreement programs often include supporting programs and policies, such as audits, assessments, benchmarking, monitoring, information dissemination, and financial incentives, which provide information, technical assistance and financial incentives to participants (Price, et al. 2003).

For example, the Netherlands has implemented the third generation of the Long Term Agreements (LTAs) since 2007. This program covers small and medium size energy users (energy consumption < 0.017 Mtce/yr)[6] and includes energy savings throughout the entire product chain. All participants are required to develop Energy Efficiency Plans and implement all profitable measures. The government provides technology list with payback periods developed at the sector level to assist participants in choosing appropriate energy efficiency measures. Benefits of participating in the program and achieving the targets include regulatory benefits and financial benefits: 1) participating and compliance companies will no longer be subject to supplementary national policy governing CO_2 reduction or energy conservation; 2) participating and compliance companies will no longer be subject to specific national energy tax; 3) participating and compliance companies will no longer pay the costs of buying carbon credits in the field of the Joint Implementation, the Clean Development Mechanism (CDM) or emissions trading (IIP, 2015c).

[6] Large industrial energy users (companies with an energy consumption of at least 0.5 PJ per year) were covered by the 1st generation LTAs from 1992 to 2000 and then were covered by the Benchmarking Covenant until 2012, and are now covered by the LTA on Energy Efficiency (LEE), which is specifically designed for enterprises that participate in the EU ETS.

3. Key Supporting Mechanisms

3.1 Information to Inform Decision-makers and Spur Competitiveness

High-quality information on energy efficiency potential and the benefits of investing in energy efficiency can give decision-makers the knowledge needed to undertake energy efficiency investments. Such information can be provided to decision-makers through studies, guidebooks, networks, and industrial associations as well as through high-quality energy audits.

3.1.1 High-quality Information on Energy Efficiency Potential Including Technology Performance, Costs, Savings

High-quality information on energy efficient technologies, as well as high-quality information regarding the overall potential for energy savings and emissions reductions in industrial facilities or industrial sectors, is essential for setting realistic energy efficiency targets, establishing energy efficiency investment plans, and spurring meaningful action. High-quality information on energy efficient technologies include information on technology performance (e.g. quality, lifetime), upfront capital and installation costs, energy savings compared to conventional efficient technologies, and other benefits such as reduced labor costs for maintenance, reduced product waste, and reduced emissions of pollutants. The information is usually supported by guidebooks, criteria and other supplemental materials to help enterprises understand and utilize the information. It can be provided or managed directly by the government, by independent entities designated by the government, or networks or organizations established by enterprises.

Sources of High Quality Energy Efficiency Information

U.S. Department of Energy's Technology Guidebooks[7]

The U.S. Department of Energy's Advanced Manufacturing Office (AMO) partners with industry, small business, universities, regional entities, and other stakeholders to identify and invest in emerging clean energy technologies. AMO has published series of guidebooks on energy efficiency technologies and measures in different industry subsectors and energy systems (e.g. motor systems, steam systems, process heating systems, etc.). Also, AMO has supported the development and publication of several energy assessment tools for industrial plants and energy systems.

U.S. Environmental Protection Agency's Energy Star Program

The U.S. Environmental Protection Agency (EPA) Energy Star Program has an Industrial Energy Management information center[8] designed to be a useful resource for industrial

[7]Link to tools published by AMO: http://www.energy.gov/eere/amo/software-tools

energy managers, and contains energy management information tailored to industries or focused on specific plant utility and process improvements. This center provides information on energy efficiency technologies through various guidebooks for each industry subsector. It also provides tools and information for energy intensity benchmarking of industrial plants (EPA, 2015).

UK's Carbon Trust

The UK's Carbon Trust is an independent entity that assists businesses and the public sector to reduce carbon emissions. The Carbon Trust identifies carbon emissions reduction opportunities and provides resources and tools to help enterprises improve energy efficiency (Carbon Trust, 2016). Carbon Trust also help the UK government manage its Energy Technology List, which provides eligible technologies and products that are qualified for tax relief based on the ECA scheme (UK Gov. 2015c).

European Learning Energy Efficiency Networks

Recently, the concept of Energy Efficiency Networks has had a significant success and interest in Europe. Learning Energy Efficiency Networks (LEEN) is a concept developed in Switzerland back in the 1990s. Since then, the approach has been successfully transferred to Germany, France and Austria. With these networks, 10 to 15 regionally based companies from different sectors share their energy efficiency experiences in moderated meetings. After the companies have formed the network, the process starts with an energy review and the identification of profitable energy efficiency measures in each company. Afterwards, the participants decide upon a joint target, which is allocated to the partners according to their efficiency potential. The subsequent networking process enables a continuous exchange on energy efficient solutions provided by the experiences of the network partners as well as external experts. The performance of each company is continuously monitored and controlled on a yearly basis. The network's operating period is typically from three to four years.

LEEN provides services such as initial energy diagnosis, survey and on-site evaluation. LEEN also provides suggestions on energy efficiency and carbon reduction measures and their economics. LEEN works with enterprises to help them set energy efficiency goals and organizes workshops and experience exchange activities. LEEN also helps to evaluate energy saving performance in the end. LEEN facilitates the communication between enterprises and provides expertise and knowledge to enterprises, which not only saves information searching and decision-making costs, but also improves energy efficiency awareness in enterprises and provides a healthy environment for enterprises to compete with and learn

[8]Link to the Industrial Energy Management Information Center: https://www.energystar.gov/buildings/facility-owners-and-managers/industrial-plants/industrial-energy-management-information-center

from each other on energy efficiency efforts. In addition, as a network and group, enterprises benefit from a louder and better voice to the government and the public, and could obtain better service from ESCOs more easily.

Government has a vital role in supporting the LEEN concept and encouraging enterprises to participate. For example, Swiss established "Carbon Emissions Law" and "Electricity Law" to either encourage or require enterprises to participate in the network to get tax relief. In Germany, after the initial establishment of the LEEN, the government improved its training and certification system for LEEN and set up energy efficiency network standard, which was later certified by ISO 50001. After these efforts, Germany included energy efficiency network into its National Energy Efficiency Action Plan. The German government could provide up to 80% of consultancy fee and financial support for some energy efficiency measures (OFWeek, 2016).

3.1.2 High-quality Energy Audits[9]

An industrial energy audit is a necessary first step for understanding a facility's energy consumption by end-use and identifying key areas for energy saving in industrial operations. An industrial energy audit can also provide important impetus for industrial facilities to implement energy-efficiency measures and technologies.

High-quality energy audits can provide detailed cost-effective analyses of all identified measures and technologies, based on a plant's specific operating conditions and can provide packages of customized recommendations for plants to consider. Energy audits are sometimes funded by the government or public utilities and are usually partially subsidized or provided entirely free of charge to industry. Energy audits could be performed through a stand-alone energy auditing program, or implemented as a supporting policy tool for policies such as voluntary agreements or emissions trading programs.

A stand-alone energy auditing program largely focuses on the energy audit itself, and asks participants to perform energy audits. An integrated energy audit program combines energy audits with other policy measures to better motivate participants, to help decision-makers set reasonable yet ambitious energy-saving targets, and to achieve the broader goals of the program. Since energy-efficient technologies and measures improve over time, energy audits should not be viewed as one-time events, but should be performed regularly and can be combined with other policies and mechanisms to continuously promote industrial energy efficiency.

[9] This section (3.1.2) and its sub-sections (3.1.2.1 and 3.1.2.2) are mainly excerpts from Price and Lu (2011).

To ensure that energy auditing programs are successful, they should be supported by regulations, standards, and guidelines for conducting standardized energy audits, collecting energy auditing results, analyzing and evaluating energy audits, as well as incentives and supporting measures for participants. Quality control and monitoring of energy audits, as well as information dissemination are also important to robust energy auditing programs. Energy audit programs should also provide training and certification of energy auditors, since they will have a significant impact on the quality and output of the energy audits. Some countries provide a directory or network of accredited auditors or consultants to perform the audits, such as Australia's (former) EEAP and Norway's IEEN and Enova (MURE II, 2005; WEC, 2003). The U.S. Office of Industrial Technologies (OIT) Best Practices Program works with the selected facility to identify potential candidates to help with the audits (U.S. DOE OIT, 2005). For large energy consumers with advanced energy efficiency programs, the UK's Carbon Trust works directly with clients to address specific needs (Price, et al. 2005a).

3.1.2.1 Stand-alone Energy Auditing programs

Stand-alone energy auditing programs were identified in six countries. These programs were established by the national governments to stimulate demand for industrial energy audits, especially for small-and-medium enterprises (SMEs). The stand-alone energy auditing programs can be grouped into two categories (see Table 3): 1) programs that offer energy audits to facilities free-of-charge, and 2) programs that provide subsidies to companies to partially cover the costs of energy audits.

Table 3. Types of Stand-Alone Energy Auditing Programs

Category	Program Examples
Free energy audits	US Industrial Assessment Centers (US Department of Energy)
	UK Carbon Surveys (Carbon Trust)
	Japan Industrial Energy Audits (Energy Conservation Center of Japan)
	Ireland Energy Advice to SMEs (Sustainable Energy and Authority of Ireland)
Subsidized energy audits	Swedish Program of Energy Audits for Companies (Swedish Energy Agency)
	French Program of Energy Auditing for SMEs (Ministry of Economy, Finance and Industry)

There are several common features of the stand-alone energy auditing programs. First, these national programs are all voluntary and are open to all interested participants. Second, except for the Program of Energy Audits for Companies in Sweden, all other programs focus on SMEs. SMEs often do not have the resources that large enterprises possess in terms of expertise and information related to energy-efficiency (Nagesha and

Balachandra, 2006; Worrell and Price, 2001; Reddy, 1991). Typically, due to the pressing issues of economic survival and limited management capacity, SMEs either are not interested in energy audits or do not have the financial resources to afford a professional energy audit. Thus, a government-initiated energy auditing program can be a convenient channel for SMEs to seek expertise or financial support.

Stand-alone energy auditing programs typically focus on SMEs and are offered for free or with the costs shared between the industry and government. Stand-alone energy auditing programs often emphasize how to build an effective, standardized, and practical system and are designed to ensure that industrial participants can implement the proposed cost-effective measures. They also emphasize that energy audits be conducted in a comparable and coherent manner, and that the results be measurable, verifiable and useful to other manufacturers. Subsidies for energy audits, training and certification of energy auditors, standardized tools and guidebooks, energy audit databases, post-audit follow-ups and dissemination of case studies are critical to a robust and high-quality stand-alone energy auditing program.

3.1.2.2 Integrated Energy Auditing Program

Many industrial energy-efficiency policies and programs include industrial energy audits as a key component which is combined with other policy measures to better motivate participants and to achieve broader goals. Sixteen programs in 14 countries and the European Union have integrated industrial energy-efficiency policy programs that include energy audits.

The integrated policy programs include voluntary agreement schemes and mandatory regulations. Voluntary agreements (agreements signed between industry and the government) have been widely used (Price, 2005) and in many cases require energy audits for participants. Mandatory requirements are regulations or legal mandates established by national governments, which often require facilities to conduct energy audits, or meet energy-efficiency improving targets, or establish a certified energy/environmental management system. Often, energy audits have been utilized as one of the effective tools to achieve broader goals of the national regulations.

Integrated industrial energy-efficiency policy programs with energy audits use an array of other policies or programs in combination with energy audits. These may include the use of certified energy or environmental management systems, requiring the establishment of energy-efficiency improvement targets or goals, requiring the establishment of energy action plans, exemptions from energy and/or CO_2 taxes, the threat of applying an energy or CO_2 tax if targets or goals are not reached, financial support for investments, subsidies for energy audits, and recognition labels and awards. Based on country-specific conditions,

energy auditing program developers (e.g., policymakers) decide which program type to use (either voluntary or mandatory), and which measures to include in their country-specific programs.

3.1.3 Providing Financial Incentives and Technical Assistance Through Benchmarking

Benchmarking has been used in a variety of programs such as allowance allocation in carbon trading schemes, voluntary programs such as Belgium's Benchmarking Covenant, and the US EPA's Energy Star Program. Benchmarking tools are provided by governments to help enterprises understand how their energy consumption compares to other similar facilities. Combined with other programs, benchmarking can be used to help reward the most efficient facilities and encourage enterprises to implement energy efficiency technologies through monetary rewards or financial incentives.

The use of benchmarking to determine the allocation of free allowances in ETS rewards the efficient facilities and encourages companies to implement energy efficiency measures. For example, Belgium's Benchmarking Covenant aimed to bring participating industrial companies to the top 10% of most energy efficient plants worldwide by 2012 through the use of benchmarking. Belgium's Benchmarking Covenant targeted energy-intensive industries with annual primary energy consumption of over 0.017 Mtce. About 180 companies were included in the Benchmarking Covenant, accounting for 80% of total industrial energy consumption in Flanders (Benchmarking Commission, 2005). The Benchmarking Covenant started in 2002 and expired in 2012, which required all targeted companies to undertake economically feasible energy efficiency measures over time to meet the goal of reaching the benchmark – top 10% most energy efficiency plants worldwide. Benefits for participants that fulfilled the Covenant obligations include free allowances in line with the committed energy efficiency improvement and exemption from additional measure or policies on energy use or GHGs emission reduction (Cornelis, 2014).

Under the U.S. EPA Energy Star program, benchmarking tools are provided for manufacturers to compare their manufacturing plants' energy performance with similar facilities nationwide. The benchmarking tools include Energy Performance Indicators (EPIs) unique to each type of manufacturing, including automobile assembly, cement, glass, food, paper and pharmaceutical manufacturing (Energy Star, 2015a). At the end of 2014, more than 130 industrial plants (out of a total of 346,000 industrial facilities in the US) have been certified as ENERGY STAR with cumulative cost savings of more than $3.5 billion and cumulative GHG reduction of nearly 35 $MMTCO_{2e}$ (Energy Star, 2015b).

Since EPA Energy Star-focused industries advance in energy management and also measure and track performance using their industry-specific EPIs, EPA can observe the progress plants are making to achieve higher levels of energy performance. Based on the progress,

EPA also update the EPI to reflect updated plant data for the industry, which also allows EPA to evaluate the energy efficiency improvements within a particular industry (Energy Star 2015c). Duke University evaluated the improvement in U.S. cement plant energy performance from 1997-2008 and found that energy intensity in the cement sector improved by 13 percent with the most dramatic change in the energy performance of the industry's least efficient plants (Boyd and Zhang, 2011).

3.1.4 Providing Technical Assistance Through Enterprise Performance Rating Systems

Many enterprise performance rating programs in the U.S. help enterprises save energy and costs, through providing technical assistance or by requiring adoption of a standardized energy management system. Enterprises that participate in the program can get assistance, guidance or training on identifying and understanding energy efficiency opportunities.

3.1.4.1 Better Plants and Better Plants Challenge Program

The U.S. DOE's Better Plants Program is a national partnership initiative to drive significant improvement in energy efficiency across U.S. industry. Manufacturers sign a voluntary agreement with DOE to reduce energy intensity by 25% over ten years with DOE. DOE in turn provides technical assistance to manufacturers to help them establish key energy performance metrics, evaluate energy saving opportunities, and organize plant-level training events. About 150 industrial companies, representing about 2,300 facilities and close to 11% of the total U.S. manufacturing energy footprint have participated in the program. The Better Plants Program is a broader-based initiative, which allow companies to make long- term commitments to energy efficiency and report their progress once a year.

Besides the Better Plants Program, the U.S. DOE also offers a Better Plants Challenge Program, which require more commitment from participating companies. The Better Plants Challenge requires partners to take on additional commitments to openly share their energy performance data and market-leading energy efficiency strategies (DOE, 2015d). Manufacturers can partner with DOE through either the Better Plants Challenge or the Better Plants Program.

3.1.4.2 Superior Energy Performance Program

In 2007, DOE partnered with the U.S. Council for Energy Efficient Manufacturing (U.S. CEEM), American National Standards Institute (ANSI), and the ANSI-ASQ National Accreditation Board (ANAB) to establish the Superior Energy Performance (SEP) Program. SEP certifies industrial facilities that implement an energy management system that meets the ISO 50001 global energy management system standard and achieves improved energy performance. An independent third party audits each facility to verify achievements and qualify it for recognition at the Silver, Gold, or Platinum level, based on performance. To date, the program participants achieved annual savings of $87,000 to $984,000 using no-

cost or low-cost operational measures, with an average of 10% reduction in energy costs within 18 months of SEP implementation and 6% to 25% improvement in energy performance over three years (DOE, 2015c).

The Superior Energy Performance program requires manufacturers to implement an ISO 50001 certified energy management system, which can identify current energy practices and energy improvement opportunities. With the implementation of an energy management system that provides data and analysis to inform decision-making, the plants are not only able to make better decisions on energy improvement, but also document their performance and increase their recognition and credibility (McKane 2014; DOE, 2015c). The SEP program provides guidance, tools and recognition, which is essential to the implementation of energy management.

3.1.5 Economic Benefits Calculations

3.1.5.1 Use of economic (IRR) criteria to determine required investments within voluntary agreements

Internal rate of return (IRR) is commonly calculated to assist decision-making in financing and investment. IRR represents a rate of return of a certain investment. Generally, the higher the IRR, the more (economically) desirable the project is. In designing industrial energy efficiency programs, IRR has been used as an indicator or a metric to gauge the desirability of proposed industrial energy efficiency improvement projects.

In Flanders, Belgium, under the Auditing Covenant (which operated from 2005 to 2014), participating industrial companies were required to develop an energy plan after joining the Covenant. The energy plan must include an analysis of on-site energy consumption and identification of energy saving measures that could be implemented by the company. Projects with an IRR of 15% or higher were required to be implemented within four years of the approval of the submitted energy plan. After the first four years of the Auditing Covenant, companies were required to submit a revised energy plan, and energy saving measures with an IRR of 13.5% or higher were required to be implemented within four years. In addition to the criteria of IRR, companies also needed to look into the technical feasibility of energy saving measures, even if they had met the minimal IRR requirements.

IRR was also used in Belgium's Benchmarking Covenant, which operated from 2002 to 2014. The Benchmarking Covenant covered the largest energy-intensive industrial facilities while the Auditing Covenant targeted medium-sized industrial companies. The program emphasized benchmarking facilities in terms of specific energy consumption against similar facilities outside Flanders, Belgium, similar facilities in other regions, or against best practice. If all of this information was missing, companies under the Benchmarking

Covenant were required to carry out an energy audit and implement energy saving measures with an IRR of 15% or higher.

Both the Benchmarking Covenant and the Auditing Covenant ended in 2014. The program succeeding them is the Energy Governance Agreements. Different from the Benchmarking Covenant, the Energy Governance Agreements do not require participants to conduct benchmarking or set energy efficiency targets. However, the program does require companies to conduct an energy audit every four years and implement energy saving measures with a minimal IRR. The threshold of the IRR rate is set as 14% for companies under the EU Emission Trading Scheme (ETS) and 12% for non-ETS participants. Both IRR rates are stricter than the Benchmarking and Auditing Covenant.

It is interesting to see the trend in Belgium's experience of voluntary agreement programs choosing to set up economic thresholds for companies to take actions, rather than imposing an energy efficiency target for the program. This choice is largely driven by potential risks of establishing energy efficiency targets for the program, such as changes in the total number of participating companies over the program's lifetime, changes in production volumes, changes in society-wide economic conditions, and assumptions that have to be made to take into account autonomous energy efficiency improvement. Thus, choosing an economic indicator (such as IRR) as a decision-making tool simplifies the program evaluation and monitoring process. However, the merits of establishing an energy efficiency target for the program should not be neglected. Having energy efficiency targets help the program to track its progress and fulfill its policy obligations. It also can be used to monitor the progress of the program for future improvement.

It is also worth noting that the use of IRR is just one component in a large, complex, and multi-faceted program. All three programs mentioned above - the Benchmarking Covenant, the Auditing Covenant, and the Energy Governance Agreements - have a list of program elements that are built-in to ensure program success. Such elements have been discussed in literature, including integrated program planning, participants commitments, government compensation, incentives and penalties, monitoring and evaluation (Cornelis, 2014; Price, 2005).

3.1.5.2 Use of costs and benefits information in energy efficiency assessments

California utilizes a combination of regulatory and economic measures to achieve its 2020 goals of reducing its greenhouse gas (GHG) emissions to 1990 levels by 2020, which were set into law through the passage of the California Global Warming Solutions Act of 2006 (AB 32). In 2011, a specific regulation on industrial facilities, "Regulation for Energy Efficiency and Assessment of Large Industrial Facilities" was approved and went into effect on July 16. The regulation requires large industrial facilities to conduct a one-time energy efficiency

assessment and determine potential emission reduction opportunities (CARB, 2011c). The energy efficiency assessment not only needs to provide information on facility's key energy consumers (such as equipment and processes) and their associated emissions but also needs to identify energy use reduction opportunities and associated impacts. For every potential project identified, the assessment needs to provide a brief project description, estimated cost information (including both one-time capital cost and average recurring annual costs), estimated average annual energy savings, associated average annual GHG emission reductions, criteria air pollutant reductions, and toxic air contaminant emission reductions, as well as estimated annual cost savings. The information on costs and benefits is presented in ranges from low cost projects to large capital expenditure projects, from projects that can be implemented quickly to mid and long-term projects, and from simple projects to projects that have extensive facility impacts. It is worth noting that the use of "costs and benefits" in California's program is included in both legislation (AB 32) and also in a policy regulation.

3.1.5.3 Providing Financial Information through Investment-grade Audits

Investment-grade audits provide a detailed account of energy use, cost savings analysis of potential energy conservation opportunities, and a project proposal that include a series of energy conservation measures with plans for financing, implementation, and savings verification (DOE, 2011). Investment-grade audits typically provide information on the Return on Investment (ROI) of facility retrofits, so that companies will know the costs, savings, and the financial return on investments of the potential energy conservation measures.

Investment-grade audits have been used in energy savings performance contracting in the U.S. Typically, ESCOs perform investment-grade audits at the facility and develop a project proposal that includes recommended energy conservation measures with financing information and projected annual cash-flow. The owner of the facility evaluates the proposal and negotiates an energy savings performance contract with the ESCO based on these results (DOE, 2015f).

3.1.6 Providing Favorable Tax Treatment or Incentives Through Technology Promotion List

Many countries provide tax reduction and other financial incentives to enterprises that install targeted energy efficiency technologies that are included in a technology promotion list. The UK's Enhanced Capital Allowance Scheme is an example of such a technology promotion list. Enterprises that invest in energy-saving technologies specified in the "Energy Technology List", can deduct the capital costs of those technologies against their taxable profits for the investment year (HM Revenue & Customs, 2008).

3.2 Reducing Energy Efficiency investment risk

3.2.1 Use of Green Bank to Reduce Investment Risk and Provide Technical Assistance

Green banks are financial institutions that assist their customers with purchase of clean energy technologies. Green banks have been established to address cost concerns and administrative complexities associated with direct incentive programs such as grants and rebates (Belden, et al. 2015).

The UK Green Investment Bank (GIB) is the first green bank to provide funding for green and profitable infrastructure projects. Supported technologies in the energy efficiency area include building retrofits (e.g. lighting, insulations, glazing), on-site generation (e.g. CHP, renewable heat, heat pumps), industrial process (e.g. motors, pumps, kilns), and Infrastructure (e.g. streetlighting, heat networks). From 2014-2015, funding of $324 million (£260 million)[10] was provided to energy efficiency projects, including sheltered housing boiler replacement, street-lighting project, data center retrofit, and a SME energy efficiency platform. The total investment in energy efficiency projects accounted for 14% of the bank's total investment (GIB, 2015).

The Union of Concerned Scientists evaluated six state governments (Connecticut, New York, Pennsylvania, Kentucky, Iowa, and Massachusetts) in the US and one national government (Germany) that have developed green banks (Belden, et al. 2015). The study shows that green banks have helped promote investments in clean energy and these clean energy financing programs have successfully engaged diverse stakeholders to help mobilize capital. The study provides some important insights on the role of government administrators and collaborative efforts (Belden, et al. 2015):

> "Government administrators have: 1) made use of in-house energy expertise to reduce the financial risks of private-sector loans for clean energy projects; 2) educated, and were educated by, the financial sector; 3) enabled a broad array of individuals, businesses, and institutions to achieve savings from clean energy investments."
>
> And collaborative efforts have also been included 1) to "make use of existing contractor networks to help roll out financing programs"; 2) to "consult with the financial community to build trust and identify sustainable funding sources"; 3) and to "draw on local utilities" experience in delivering programs to their customers to avoid duplication and maximize effectiveness.

3.2.2 Loans and Grants to Provide Financing

The DOE Loan Guarantee Program was created in 2005 under Section 1703 of Title XVII of the Energy Policy Act of 2005 to support innovative clean energy technologies that are

[10] 1 British Pound=1.245 US Dollar as of November 3, 2016.

typically unable to obtain conventional private financing due to high technology risks. These technologies include: biomass, hydrogen, solar, wind/hydropower, nuclear, advanced fossil energy coal, carbon sequestration practices/technologies, electricity delivery and energy reliability, alternative fuel vehicles, industrial energy efficiency projects, and pollution control equipment (DOE, 2015e).

The UK's Carbon Trust provides interest-free loans to small- and medium-sized enterprises (SMEs) (Carbon Trust, 2008). Interest-free loans are now available to eligible SMEs in Wales and Northern Ireland that wish to upgrade to more energy efficient equipment and renewable technologies. Carbon Trust provides $1,246 of loan for every 1.5 tCO_2 energy efficiency project is expected to save per annum within the range from $2,729 to $249,290[11] (Carbon Trust, 2015).

Australia implemented a Clean Technology Investment Program in 2012. It provided $615 million (800 million AUD)[12] grants for over 7 years for capital investment in energy efficient equipment and low emissions technologies, processes and products. Manufacturers that meet a minimum energy or emissions threshold can apply (IEA, 2015).

3.2.3 Public Private Partnerships to Mobilize Energy Efficiency Investment

Public-private partnerships (PPPs) for energy efficiency finance are "mechanisms that use public policies, regulations, or financing to leverage private-sector financing for energy efficiency projects" (IEA, 2011). There are three main forms of PPPs in the energy efficiency area: 1) dedicated credit lines; 2) risk-sharing facilities; and 3) energy performance contracting (EPC).

Dedicated Credit Lines

Dedicated credit lines are mechanisms to encourage local financial institutions (LFIs) to offer sub-loans to implementers of energy efficiency projects. Public entities, such as government, international financial institutions, and donor organizations, provide funds to private-sector organizations such as banks and LFIs, at a low interest rate to encourage them to provide and lend more funds for energy efficiency projects, which usually have higher interest rates. Local financial institutions earn profits from these loan transactions (IEA, 2011).

Dedicated credit lines help LFIs improve their awareness of the benefits and characteristics of energy efficiency financing. Public entities leverage dedicated credit lines to encourage LFIs to provide funds to expand the scale of the fund available for financing from public

[11] 1 British Pound=1.245 US Dollar as of November 3, 2016. Carbon Trust provides £1,000 of loan for every 1.5 tCO_2 energy efficiency project is expected to save per annum within the range from £3,000 - £200,000.
[12] 1 Australian Dollar=0.77 US Dollar as of November 3, 2016.

entities. Governments also provide technical assistance to LFIs to build and enhance the capacity of LFIs (IEA, 2011).

For example, Thailand initiated the Energy Efficiency Revolving Fund (EERF) in 2003 to incentivize financial institutions in Thailand to lend for energy efficiency measures (Grüning et al. 2012). For industry, eligible projects included "improvement in combustion efficiency of fuels; prevention of energy loss; recycling of energy wastes; substitution of one type of energy by another; more efficient use of electricity through improvements in power factors, reduction of maximum power demand during peak demand, use of appropriate equipment and other approaches; and use of EE machinery or equipment as well as use of operation control systems and materials that contribute to energy conservation" (IEA 2011). The source of funding for the EERF was the government budget collected from a tax on petroleum products.

The EERF was successful in stimulating financial institutions in Thailand to finance energy efficiency, and also represented a shift in the role of government from "enforcer and regulator to facilitator and supporter" (Grüning et al. 2012; USAID, 2009). Success factors included: 1) simplified procedures for project application, appraisal, reporting, and loan processing; 2) offering loans with interest rates lower than the market rate to attract commercial banks; and 3) technical assistance and education from the Department of Alternative Energy Development and Efficiency (DEDE) (IEA 2011, Grüning et al. 2012, USAID 2009). To obtain EERF financing, the owner of an industrial or commercial facility or ESCOs conducted energy audits to identify energy efficiency projects. Then commercial banks conducted financial analysis of the project if they have the technical staff, and if not, DEDE helped them conduct the technical assessment (USAID, 2009). A DEDE official also paid a visit to all banks in Thailand to promote the EERF and explain the application process and the eligibility criteria (Grüning et al. 2012).

Streitferdt and Chirarattananon (2015) explain, however, that an external financial mechanism such as EERF can damage the market and impede it from becoming mature since the mechanism couldn't "induce banks to experiment with different credit provision models" and the technical support was superficial and failed to sufficiently "transfer the technical and credit lending advice to the banks". They also pointed out the there is a lack of demand for energy efficiency projects and finance from customers, which may result from a lack of mandatory regulation on energy efficiency improvement or a lack of implementation and enforcement of these regulations (Streitferdt and Chirarattananon, 2015).

Risk-sharing Facilities

Risk-sharing facilities are mechanisms where a public entity offers guaranteed product to reduce energy efficiency project financing risks to private sector. Government, multilateral

banks, or donor organizations absorb some energy efficiency project financing risks by providing a partial guarantee that covers a percentage of the loss due to loan defaults. Risk-sharing facilities also include some technical assistance and capacity building, as in the case of dedicated credit lines (IEA, 2011).

Two examples of risk-sharing facilities are the Commercializing Energy Efficiency Finance (CEEF) Program in Europe that operated from 2003 to 2008 and the Partial Risk Sharing Facility for Energy Efficiency (PRSF) in India since 2015. The CEEF was launched by the International Finance Corporation (IFC) and the Global Environment Facility (GEF). The PRSF was an agreement between the World Bank and the Indian government with funding from GEF and the Clean Technology Fund (CTF) under the Climate Investment Fund (CIF). Both programs have a risk sharing component where IFC or the Small Industries Development Bank of India (SIDBI) guaranteed a certain amount of project risk to the participating financial institutions. The CEEF offers 50% of the project risk and PRSF guarantees the partial credit to 40-75% of the energy efficiency loan (IEA, 2011; WB, 2015).

The two programs also have technical assistance and capacity building components, which help financial institutions market and develop their energy efficiency financial services, prepare projects for investment, improve capacities for EE project financing, and help ESCOs to develop EE projects and their business capacities. Technical assistance is considered very important and participants appreciated the trainings and seminars provided (IEA, 2011). It is also very important to have a local presence from the granting agency in the countries where the program is implemented, as local staff of the agency can help participants to continue their work and ensure take-off of the projects (IEA, 2011).

The market maturity of energy efficiency and general acceptance of the guarantee product is also very important. The IEA points out that the CEEF has been more successful in the countries with more developed energy efficiency markets than in the countries where financial institutions are less interested in energy efficiency financing and there are fewer ESCOs (IEA, 2011).

Energy Performance Contracting and ESCOs

Energy Performance Contracting (EPC) is a mechanism that uses private sector investment and expertise to deploy energy efficiency retrofits in buildings, industries, and other types of facilities (Shen, et al. 2015). ESCOs and public agencies will make performance-based agreement and ESCOs will get payments contingent on demonstrated performance (IEA, 2011).

About 40 countries around the world have ESCO activities. ESCOs started in the US, Canada, Sweden and the UK in the 1970s and early 1980s, and were then established in many other

countries in the late 1980s, 1990s and even today (Vine, 2005; Goldman, et al. 2005). Studies on the experiences of these countries have identified the following success factors and actions to further promote ESCOs (Vine 2005; Bertoldi, et al. 2006):

1) Provide training to energy managers and financial institutions to increase their awareness of ESCO services and projects. To disseminate ESCO information, a third-party financing network can also be established to include all key players in the market, including ESCOs and their associations, energy efficiency agencies at the national and local level, financial institutions, equipment manufacturers, and other stakeholders.
2) Establish accreditation systems for ESCOs, such as the US ESCO accreditation system implemented by the National Association of Energy Service Companies (NAESCO), to ensure that they provide qualified and reliable service.
3) Develop funding and financing sources for ESCOs to market, prepare, and develop their projects. Funding sources could be traditional, such as private financial institutions, multi-lateral funders such as the World Bank and IFC, and could also be innovative, such as revolving funds.
4) Standardize energy performance contracts, and measurement and verification (M&V) so that facilities and financial institutions can better understand and develop EPCs. For example, NAESCO worked with industry to develop the International Performance Measurement and Verification Protocol (IPMVP), which is used to measure and evaluate energy-efficiency projects.

These three approaches - dedicated credit lines, risk-sharing facilities and EPC - can be applied in different market environments. Dedicated credit lines are most suitable in financial markets that are less mature and LFIs are in need to provide better understanding of the benefits and characteristics of energy efficiency projects. Dedicated credit lines also require greater funding from public sectors as they have to finance LFIs (IEA, 2011). Risk-sharing programs are applicable to markets that are somewhat mature and LFIs want to finance energy efficiency but are worried about the high risks associated with those projects (IEA, 2011). EPCs are most useful in mature financing markets with enough liquidity of LFIs and enough awareness and capability to provide energy efficiency financing. EPCs have the potential to scale up LFI financing, which is difficult to achieve through dedicated credit lines and risk-sharing programs (IEA, 2011).

3.2.4 Tax Incentives to Incentivize Energy Efficiency Investment

As mentioned above in the technology promotion list with tax incentives, many countries have utilized tax incentives and tax relief to boost investment in energy efficient products, equipment, and technologies. IEA (2015, 2012) identified 13 IEA countries that have implemented tax relief programs for industrial equipment: Belgium, Canada, France,

Germany, Ireland, Italy, Japan, the Republic of Korea, Netherlands, Norway, Portugal, the United Kingdom, and the United States.

Tax rebates are programs in which companies deduct the cost of energy-efficient equipment from their annual profits and are found in Japan, Korea (Republic of), the Netherlands, and the UK. In the Republic of Korea, a 5% income tax credit is available for energy-efficiency investments such as replacement of old industrial kilns, boilers, and furnaces; installation of energy-saving facilities, co-generation facilities, heat supply facilities, or energy-saving equipment; alternative fuel using-facilities; and other facilities that reduce energy use by 10% (UNESCAP, 2000). In Japan, there is a "Green Investment Tax Reduction" program to provide small and medium enterprises business operators that purchase eligible energy savings or CO_2 emissions reduction equipment with a special depreciation of 30% against the standard purchase prices or a 7% tax deduction (IEA, 2016).

In the Netherlands, under the Energy Investment Deduction (Energie Investeringsaftrek, EIA) program, originally 40% and now 55% of the annual investment costs of energy saving equipment can be deducted from the fiscal profit of the calendar year in which the equipment was procured, up to a maximum of US $116 M (€107M). Qualifying equipment is provided on an "Energy List" and the costs associated with obtaining advice for purchased equipment can also be included. Approval is granted by SenterNovem, an agency under the Dutch Ministry of Economic Affairs. The UK's Enhanced Capital Allowance Scheme discussed above is also an example of tax relief, which provides 100% write-off in the first year of purchase (Price, et al. 2005b). Germany has implemented a Tax Cap ("Spitzenausgleich") since 2013, which provides tax relief for industrial companies that take energy efficiency measures such as implementation of energy management systems and achieving energy efficiency targets that are required for receiving the exemption (IEA, 2015).

However, the real effectiveness of tax relief is difficult to measure because of limited data and free-rider issues[13] (Ryan, et al., 2012; Price, et al. 2005b). Programs should be designed such that they avoid providing tax relief for technologies that are already profitable (de Beer et al., 2000).

3.3 Third-party Participation to Support Energy Efficiency Policies and Programs

3.3.1 Third-party Participants to Enhance Monitoring, Verification, and Enforcement

The monitoring, reporting and verification components of many programs need third-parties to participate in the process. In the UK CCA program, verification of the company reports was based on sample audits by an independent agency (paid for by the government); full verification of all results was not undertaken in order to minimize costs.

[13] The free rider issue "is a market failure that occurs when people take advantage of being able to use a common resource, or collective good, without paying for it, as is the case when citizens of a country utilize public goods without paying their fair share in taxes". (Investopedia, n.d.)

Data on progress towards sector targets was also collected from member companies and reported by the sector associations. Sector associations were required to demonstrate to the auditors that they had maintained the accuracy of the data obtained from operators and that they had a system in place to ensure its continuing accuracy.

In the California ETS program, AB 32 requires major emission sources to report GHG emissions (AB 32, 2006). The Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (MRR) is applicable to industrial facilities, fuel suppliers, and electricity importers (CARB, 2015a). All GHG emissions data reports must comply with regulatory requirements and be submitted via the Cal e-GGRT reporting system[14]. Affected emission sources must report emissions annually and provide third-party verification of reported emissions (EPA, 2014). The MRR requires an intensive independent verification in the first year of each compliance period, with less intensive verifications every other year (CARB, 2015a). Third-party verifiers are private firms that must follow the state regulations and are approved by CARB. The CARB website provides a list of accredited verification bodies (CARB, 2015b). The verification requirements vary by sector. Sub-article 2 of the MRR lists the different methodologies for verification for industrial, electricity, and refining sectors (CARB, 2015a).

3.3.2 Designated Professionals (audit, verification, energy management) to Ensure the Success of Associate Energy Efficiency Programs

Industrial Assessment Centers and Audits

DOE Industrial Assessment Centers (IAC) are state and local solution centers that support state, local, tribal, and K-12 school district leaders by providing resources to advance successful, high-impact clean energy policies, programs and projects. Since 1976, IACs have offered free energy audits to SMEs if the manufacturers meet certain requirements (DOE, 2015a). IACs are located at 24 universities around the country and conduct energy audits to identify opportunities to improve productivity, reduce waste, and save energy. Since 1976, more than 16,000 manufacturing firms have participated in the energy audits and an average of 50% of the recommended measures were implemented (IAC, 2015). Since 2006, IAC assessments have identified more than US$595M in energy savings and nearly 4.0 million metric tons in carbon dioxide (CO2) emissions reductions. A typical IAC plant will receive more than US$47,000 in annual benefits from each assessment (DOE, 2015b).

3.3.3 Industrial Representatives to Provide Voice for Enterprises

Industrial representatives and organizations, such as industry trade groups in the U.S., Japan, and Europe, are very important as they speak for the enterprises, provide a platform for enterprises to share information, and influence government decision-making.

[14] The Cal e-GGRT reporting system can be found at https://ssldev.arb.ca.gov/Cal-eGGRT/

UK Confederation of British Industry

The UK Confederation of British Industry (CBI) was founded in 1965 and is a membership organization. It is the UK's premier business lobbying entity. It provides a voice for employers at a national and international level for a competitive policy landscape to promote the conditions of all sizes and sectors of businesses in the UK. It generates reports on energy efficiency policy and strategic areas to help businesses realize energy efficiency opportunities and help influence government decision-making. It identifies recommendations for both government and businesses to raise awareness of the benefits of energy efficiency, drive demand for energy efficiency measures and shape a holistic energy efficiency strategy that benefits all (CBI, 2015; CBI, 2013).

4. Conclusions and Policy Recommendations

Based on the review of a series of international energy efficiency policies and programs, it is recommended to design different policies targeted at overcoming different barriers to incentivize enterprises to improve energy efficiency. In addition, the synergy between different policies is beneficial to amplifying their effectiveness. Policies are also effective if they can provide a long-term and clear signal to enterprises for energy efficiency improvement and can be adjusted as the situation changes.

Different policies and measures target different needs and apply under different conditions. Voluntary agreements are effective especially when regulations are difficult to enforce; government grants are very effective for the development and commercialization of new technologies and should support both high risk with potential high pay-off projects and lower risk with incremental improvements projects; financial incentives are effective for new technologies that are just commercialized and have high capital cost, but have a good prospect of cost reduction as the market of the technologies gets expanded or learning occurs (Geller, et al. 2006) .

Specific policies and programs need to go hand-in-hand to incentivize enterprises to improve energy efficiency. Few single instruments can overcome all barriers for energy efficiency. As shown through international experiences, policies and programs usually use a combination of several instruments to amplify their effectiveness. For example, the market-based ETS programs in the EU and US not only put a price on carbon, but usually include measures to provide information and technical assistance such as energy efficiency assessments to help enterprises identify cost-effective opportunities, as well as some financial incentives such as tax relief to further incentivize enterprises. Voluntary agreements in the EU also come with financial incentives, technical assistance and regulatory benefits or punishment. Similarly, measures to provide information, such as the technology promotion lists, energy audits, and the US Energy Star Program, also need to be complemented with financial incentives and voluntary agreements to become more

effective (Geller, et al. 2006). Designing a suit of policies can also help overcome some of the shortcomings with certain policies. For example, energy audit programs may cause some free-ridership, which could be overcome by targeting specific customers. In many countries like Denmark, the Netherlands and Sweden, energy audits are provided as a benefit for participants in voluntary agreements (Price, et al. 2005a). Different types of measures help enterprises increase awareness and equip enterprises with the capability to improve energy efficiency both technically and financially, and also improve the effectiveness of the programs.

Long-term and dynamic energy efficiency policies and programs are needed. Policies and programs for energy efficiency need to be in place for more than 10 years and evolve accordingly to make sure the energy efficiency market can be established in an orderly manner (Geller, et al. 2006). For example, it requires substantial time, money, and effort to establish the appropriate institutional framework and enabling environment to convert energy efficiency potential into real investments and it has also taken many years and substantial support for ESCOs to become mainstream in North America and elsewhere (Sarkar and Singh, 2010).

Persistent policies and programs provide a clear and stable signal to enterprises, which help them take these policies and programs into account in their long-term management and investment decisions. Concerns about whether a policy is going to last can impede enterprises from making investment in new technologies as their payback period may be longer than the duration of the policy. In addition to keeping policies stable and predictable, revisions of policies to adjust to market changes are also necessary. For example, financial incentives need to keep pace with the level of commercialization and deployment of energy efficiency technologies. When the technology is well-established and already cost-effective in the market, financial incentives may be removed and provided to other emerging technologies. Many international experiences have shown this pattern. For example, the ETS in both the EU and California started with pilot periods and gradually became more active as the scheme was modified and participants become more prepared. Voluntary agreements in many EU countries have also existed for two decades, evolving over time to better enable the improvement of energy efficiency in enterprises.

More specifically for China, to help companies improve energy efficiency more actively and innovatively, it is critical to develop policies and programs focusing on the following areas:

1) Identification energy efficiency potential

ERI's survey results show that companies are in need of practical information on technologies and products, even though the Chinese central-government and local governments have published a series of catalogues on energy efficiency technologies. This shows that companies need more customized expertise and detail-oriented services from

the government or third-party organizations related to energy diagnoses, energy audits, and energy management systems, with economic analysis included.

2) Workforce development

ERI's survey results also show a key challenge that companies face is a lack of technical expertise and personnel in the energy efficiency and energy management area. Training and workforce development is needed in different industrial sectors and for different levels of personnel within in a company, and on a continuous basis. Different industrial sectors have different requirements and measures for energy efficiency improvement, so specific training targeting a particular sector is most practical and valuable to the sector. Similarly, different levels of employees in the company have their own duties and responsibilities. For example, technicians need to understand the equipment and operations, mid-level managers need to understand the technologies and analysis of different measures, and high-level executive leadership needs to understand the overall importance and the policies.

3) Market channels for energy efficiency financing

The most important issue that companies raised in the survey is a lack of funding and financing methods. This problem may worsen under China's economic "new normal" as many energy-intensive companies are facing over-capacity and bad financial conditions, which makes it difficult for them to obtain financing from traditional financial institutions to implement energy efficiency measures. Learning from international experiences, establishing and exploring market-based financing channels for energy efficiency financing, such as energy efficiency revolving funds, could be effective.

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