Energy Policy 39 (2011) 6532–6550

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Review of policies and measures for energy efficiency in industry sector ☆

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ARTICLE INFO

Article history:
Received 10 December 2010
Accepted 28 July 2011
Available online 12 August 2011

Keywords:
Industry energy efficiency
Policy review
Typology and categorization

ABSTRACT

Energy efficiency in industry plays key roles in improving energy security, environmental sustainability and economic performance. It is particularly important in strategies to mitigate climate change. The evidence of great potential for cost-effective efficiency-derived reductions in industrial energy use and greenhouse gas (GHG) emissions have prompted governments to implement numerous policies and measures aimed at improving their manufacturing industries' energy efficiency. What can be learned from these many and varied initiatives? This paper provides foundation for policy analysis for enhancing energy efficiency and conservation in industry, by surveying more than 300 policies, encompassing about 570 measures, implemented by governments in IEA countries, Brazil, China, India, Mexico, Russia and South Africa. It outlines the measures' main features, their incidence of use, and their connections with specific technical actions and key stakeholders (i.e., how and where measures affect the energy efficiency of industry). It also examines the key features underlying the measures' success: (1) potential to reduce energy use and CO_2 emissions cost-efficiently; (2) ease of policy development, execution and assessment and (3) ancillary societal effects.

0. Introduction

Since 1970s, energy efficiency and conservation have become one of key component to address energy security. Recently, it is also regarded as effective ways for reduction in GHG emissions from fossil fuel to mitigate climate change as well. This paper focuses on industry and provides foundation for policy analysis for enhancing energy efficiency and conservation in industry.

Industry sector has been consuming much energy at their various processes. Total final energy use in industry was 2.4 Gtoe globally in 2006 which was calculated from IEA statistics (IEA, 2009a), it consumes nearly one third of total global primary energy supply and 36% of energy-related CO_2 emissions. The potential primary energy savings in industry for adopting best practice commercial technologies is estimated to be 25–38 EJ/year in 2004(IEA, 2007a). This is 18–26% of the total industrial energy consumption and 5.4–8.0% of total energy consumption in all sectors. Industry's final energy use has grown by 65% between 1971 and 2005. The existing scenario analysis showed that industrial CO_2 emissions continuing to increase by 1.7 times by 2030 (IEA, 2008b).

Industry's large energy use and vast potential for energy savings make it an attractive target for improving energy security and climate mitigation through increased energy efficiency. The attractiveness is muted, however, by the policy challenges inherent in its great diversity. The sector's energy use is influenced by its many different technologies, processes and products; energy sources and prices; political, economic and business situations and managerial priorities and decision making paradigms. Further, its energy efficiency can be improved by a wide variety of technical actions (Fig. 1), including:

- maintaining, refurbishing and retuning equipment to counter natural efficiency degradation and to reflect shifts in process parameters;
- retrofitting, replacing and retiring obsolete equipment, process lines and facilities to new and state of art technologies;
- using heat management to decrease heat loss and waste energy by, for example:
  - proper use of insulation;
  - utilization of exhausted heat and materials from one to other processes;
- improving process control, for better energy and materials efficiency and general process productivity;
- streamlining processes—eliminating processing steps and using new production concepts;
- re-using and recycling products and materials;
- increasing process productivity—decreasing product reject rates and increasing materials yields.

Policy facilitates those technical efforts. The successful use of policy for energy efficiency improvement depends on how policy can finally give incentives for each possible technical improvement, directly or indirectly, to industry sector.

☆ This paper had been initially prepared during the author's career at the International Energy Agency (IEA). However, it does not necessarily reflect the views of the IEA and the IEA member countries.

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doi:10.1016/j.enpol.2011.07.058

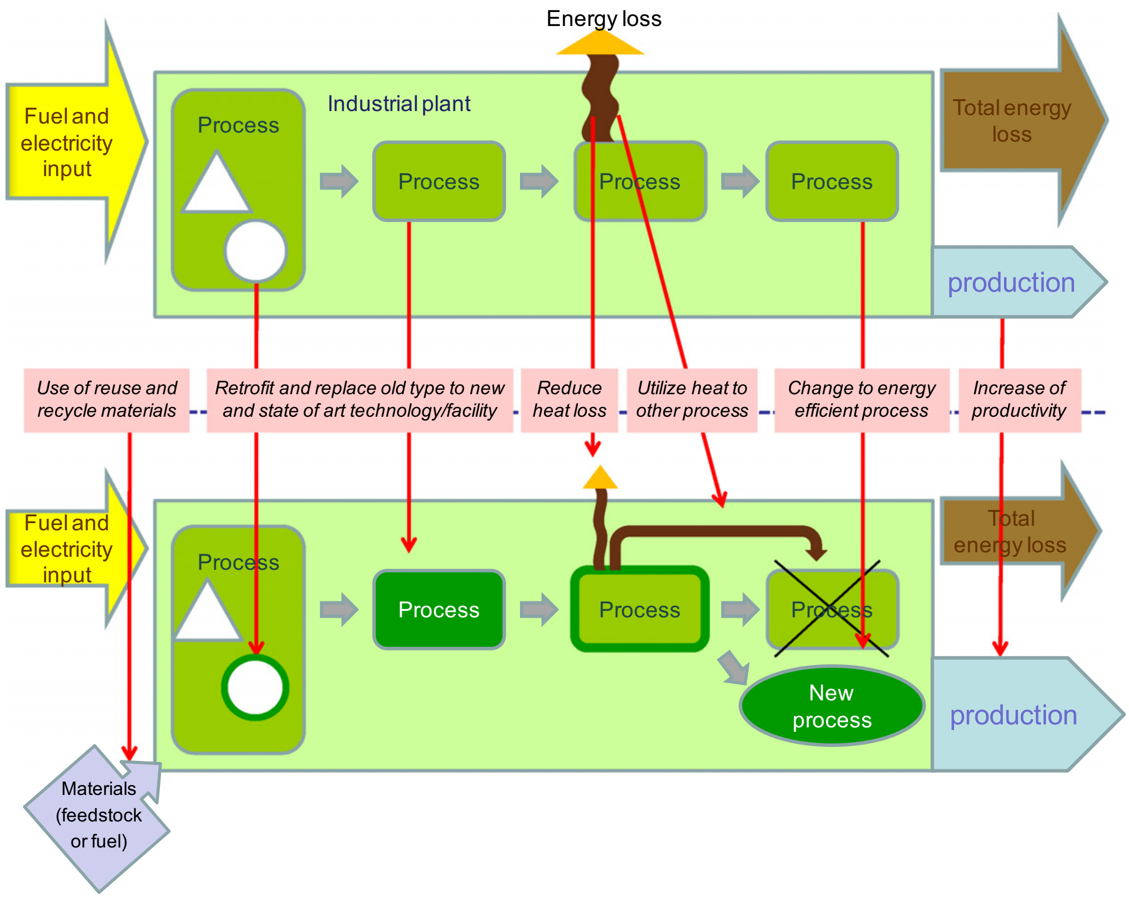


Fig. 1. Sample of technical means of energy efficiency improvement.

This paper presents a contextual framework for analyzing the operation of industrial energy efficiency policies within these diverse circumstances. It portrays "how and where policies provide incentives to industry to promote energy efficiency". It covers: policies and measures which directly and indirectly influence energy (fuel and electricity) consumption and efficiency of manufacturing process of IEA member countries and Brazil, China, India, Mexico, Russia and South Africa.[1]

1. Overview of energy efficiency policy in industry

1.1. Policy objectives

The number of energy efficiency and conservation-related policies is growing and shifting in focus. Fig. 2 shows the transition of the policies' primary purposes. One trend has been the shift from energy conservation (aimed at absolute energy savings) to energy efficiency (aimed at reducing the energy used per level of production output). Another trend has been the increasing emphasis on climate change and sustainable development objectives in recent years, especially since the Rio Summit[2] in 1992, and COP3 in 1997. International initiatives such as G8 Gleneagles Summit in 2006 have also influenced the recent increasing focus on energy efficiency/conservation and climate change.

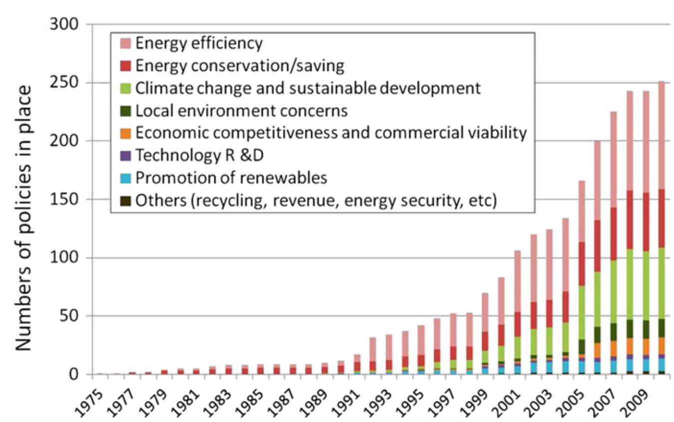


Fig. 2. Transition of objectives of policy which contribute energy efficiency improvement in IEA countries and plus 5 countries. *Note*: these numbers show numbers of policies being implemented in each year, but does not show the year of introduction. In case that one policy has multiple objectives, number is equally distributed.
Sources: IEA policies and measures database (IEA, 2010), supplemented with information from the web site of each country's energy efficiency authority and published reports.

1.2. Various policy targets for energy efficiency in industry

Governments use two general policy approaches and various streams of influence to encourage industry to improve its energy efficiency (see Fig. 3). The general approaches are: (1) company- or

[1] The paper excludes policies focused industry's use of appliances/equipment, such as lighting, office equipment and space heating/cooling/ventilation, in its buildings and on its use of automobiles, trucks and other modes of transport to convey raw materials, products and employees. Policies that encourage on-site combined heat and power (CHP) by industry are included, but those related to CHP in the power generation industry are excluded.

[2] UNCED: UN Conference on Environment and Development.

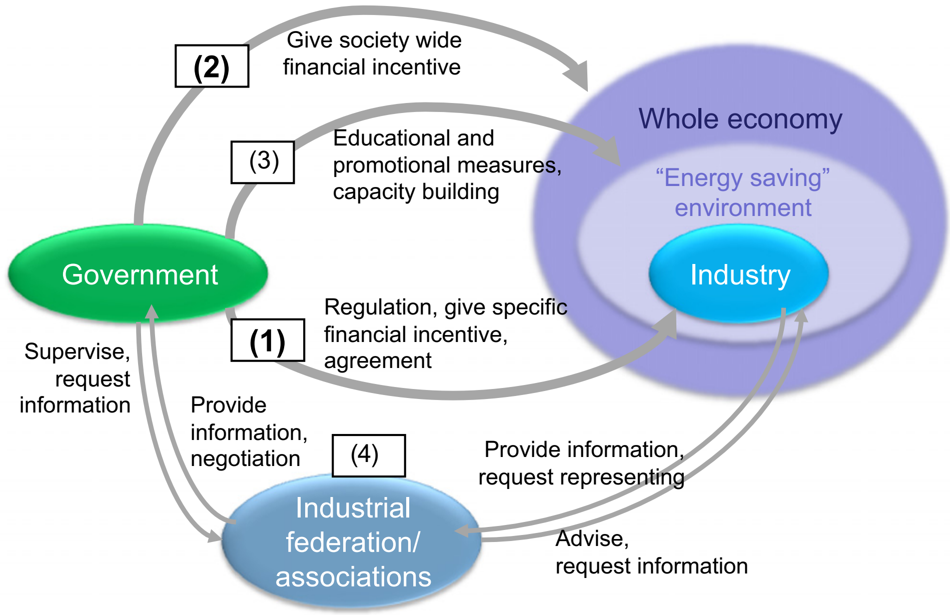


Fig. 3. Incentive and information "streams" between government and industry.

sector-specific measures, and (2) industry- or economy-wide measures focused on the environmental and social circumstances within which the companies and sectors operate. The measures (1) include regulations, directed financial instruments and agreements; the measures (2) include energy taxes, carbon taxes and emission trading. (3) There are even other policies which create an environment for the industry to enhance energy conservation, for example, education and training. (4) Industrial associations or federations, acting as intermediaries between government and individual industrial companies, can help in assessing circumstances by collecting, compiling, aggregating and communicating data which can be used for policy development and policy positions of the industry. They can represent groups of industries in negotiations, and keep company information confidential if required. For government, the easier access to industrial data, opinions or co-operation—compared with separate communications with individual companies—decreases the transaction costs of policy making. Another advantage is that government can organize a more participatory policy regime with industry which has benefits for policy design and management. For example, Stigson et al. (2009) concluded that increases of the risk perceptions of policies have negative effects in industry investment calculus, which can be overcome by the improved participatory policy regime such as dialog or policy learning, collaboration.

As described above, industry's possibilities for using energy more efficiently involve many technical actions implemented under diverse political, economic, business and managerial circumstances. In theory, energy efficiency policies could target each of these elements. Fig. 4 shows schematically the various components related to industry energy efficiency. Yellow arrows are targets to which policy would be applied for energy efficiency improvement in industry. Examples of policies possibly applied to each arrow are listed under the figure.

1.3. Typology of policies and measures

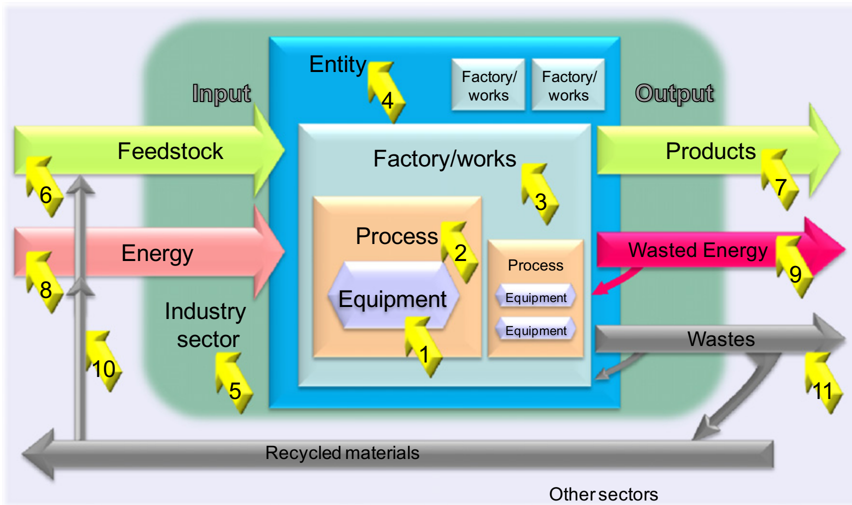
To coherently observe "how and where policies provide incentives to industry to promote energy efficiency," This paper organizes the analysis according to three main policy groups: prescriptive, economic and supportive policies,[3] which are evaluated qualitatively according to three key components of policies' success (summarized in Table 1 and Fig. 5).

Prescriptive policies are regulations, mandates and agreements that directly compel specific actions by, or communicate expectations to, industry companies and/or associations. Negotiated agreements are usually treated, together with voluntary action or plans, as self-action. (IEA, 1997) (Morgenstern and Pizer, 2007a) However, in this paper, they are classified as prescriptive measures, since governments and industries are involved and make actual promises. Regulations and agreements can target many aspects of industrial energy use: (1) equipment efficiency levels, (2) plant or process efficiency levels or configurations and (3) energy management activities.

Economic policies are taxes and tax reductions, directed financial support (e.g., subsidies and loans), cap and trade schemes, and differentiated energy prices that seek to influence the cost-effectiveness of technical actions. CO_2 cap and trade schemes are categorized in this paper as economic measures. They contribute to improving the energy efficiency of industry, because of the tight link between CO_2 emissions and energy use, though energy efficiency is not their primary purpose.

Supportive policies are energy efficiency opportunity identification tools (e.g., data collection, energy audits and benchmarking), cooperative measures (e.g., government-industry challenges and partnerships), capacity building and technical information and assistance information which help to establish a favorable environment in which industry implement energy efficiency actions more easily. Government can also lead partnership and

[3] Two other policy types are not included in this analysis: (1) government-sponsored research, development and demonstration (RD&D) and (2) direct government investment. The features of government-sponsored RD&D—ranging from basic science research to the application-specific technology development—are very project specific. The RD&D projects are too numerous and too uncertain in the extent and timing of their effects to be compiled and assessed for this project. Direct government investment in energy efficient industrial equipment and processes is rare, even when companies are state-owned.



Number in Figure	Examples
1	efficiency standard for equipment
2	energy intensity benchmarking for specific process
3, 4	reduction target of energy consumption, energy audit, subsidy, tax exemption, specific agreement
5	voluntary agreement with industrial group/association, tax exemption to certain industrial sectors, partnership/programs, emission trading
6,7	measures recommending certain kinds of raw materials or products which can increase process efficiency, government procurement of goods produced with low energy consumption
8	energy and carbon tax schemes, emission trading
9	regulation for emission of exhausted gas which has heat to be used
10	use of or restriction of reused or recycled materials as energy/feedstock
11	regulation for waste treatment

Fig. 4. How and where policies address energy efficiency improvement in industrial sector.

Table 1
Typology of energy efficiency policy for industry sector.

Policies	Examples of measures
Prescriptive	
Regulations for equipment efficiency	Efficiency standards
Regulations for process efficiency and configuration	Benchmark targets and/or energy saving goals process prescriptions
Regulations for energy management	Energy management standards
	Preparation of conservation plans
	Appointing internal energy manager and employing external energy adviser
Negotiated agreements	Benchmark targets and/or energy saving goals
	Preparation of conservation plans
Economic	
Energy taxes	Taxes
Directed energy tax reductions	Tax differentiation/exemptions, credits and deductions
Directed financial incentives	Preferential loans
	Subsidies and rebates
Cap and trade schemes	GHG emissions trading
Differentiated energy pricing	Energy tariff controls
Supportive	
Identification of energy efficiency opportunities	Collection of energy consumption data
	Collection of technology installation information
	Monitoring
	Energy auditing
	Benchmarking
Cooperative measures	Challenge and partnership programmes
	Promotion
Capacity building	Advisory services, training and education

programs together with multiple companies and/or whole sector. These correspond to the arrow (3) in Fig. 3.

It is noteworthy that most energy efficiency policies and measures are not used in isolation, but are often part of policy packages. Furthermore, the introduction of one policy does not necessarily imply the removal of pre-existing policies applied to the same entities. These aspects demand attention to policy coherence to maintain overall efficacy and cost-efficiency.

Fig. 5 correlates the concepts of "Where policies can address energy efficiency improvements" (see Fig. 4) with the "Typology of energy efficiency policies" (see Table 1. It describes what types of policies are used in what contexts. It also shows the scale of each measure. When the scale is small, such as equipment, many measures are needed to attain certain energy saving levels. This entails numerous procedures and incurs high transaction costs, On the other hand, measures applied to large targets, such as the whole economy or entire companies, have lower relative transaction costs. However, because such measures give companies greater degrees of freedom and flexibility in their compliance actions, their effects are more difficult to quantify.

1.4. Implementation trends and patterns

Fig. 6, Fig. 7 and Table 2 depict the patterns and trends in the number of energy efficiency policy measures used in the subject countries, based on a survey of 304 policies, encompassing 570 measures.[4] The use of all types of measures has increased

[4] The information was compiled from the web site of each country's energy efficiency authority, available reports and the IEA policies and measures database,

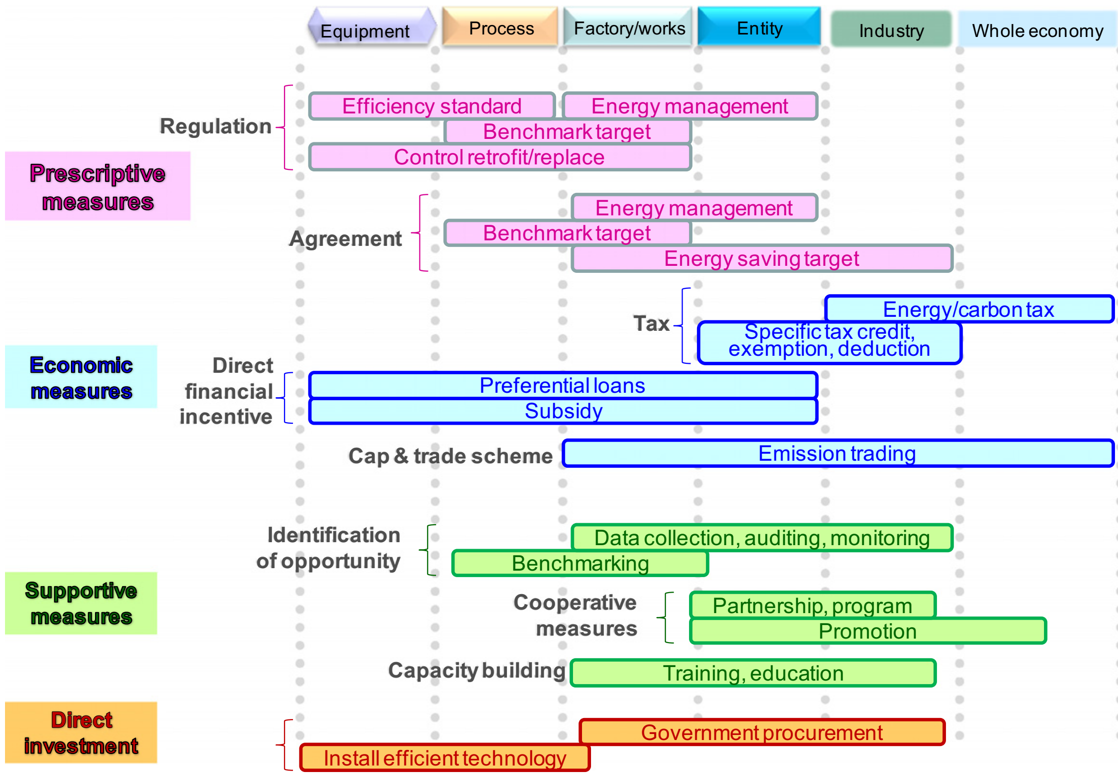


Fig. 5. Object coverage of energy efficiency policy in industry.

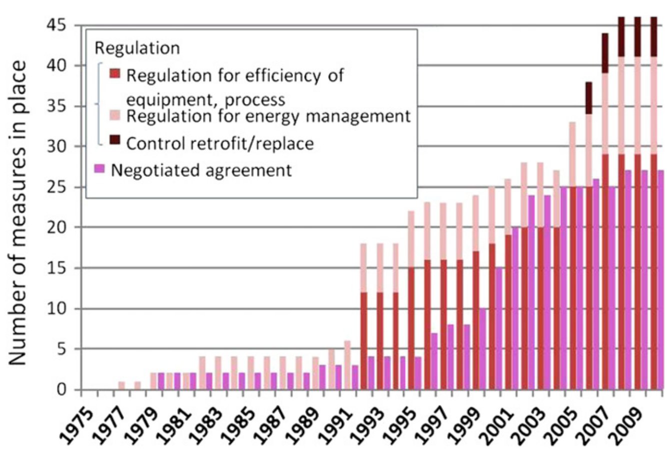


Fig. 6. Transition of implementation of prescriptive measures to promote industry energy efficiency.

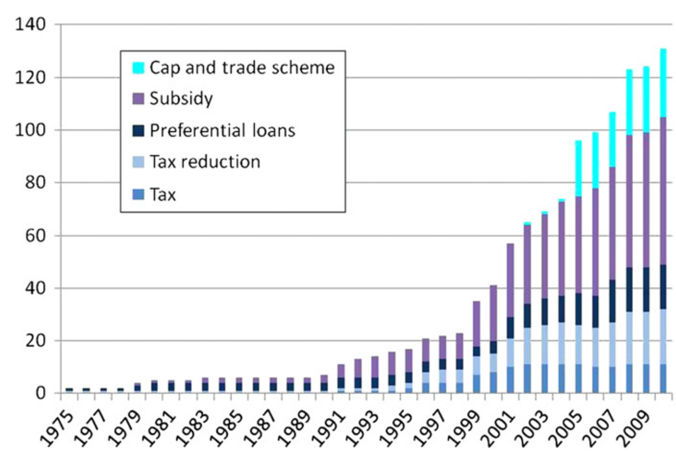


Fig. 7. Transition of implementation of economic measures to promote industry energy efficiency.

appreciably since the late 1990s. As of 2010, supportive policies are the most prevalent category (40% of all measures), followed by economic policies (35%) and prescriptive policies (24%). Identification of energy efficiency opportunities (e.g., data collection and audits) are the most popular individual measure, followed by subsidies, regulations for equipment efficiency and negotiated agreements. Among prescriptive policies, regulations for equipment efficiency have increased dramatically since 1992 when European Council Directive on boiler efficiency standard entered into force, as the directive is counted as a policy implemented in each EU member country. Regulations for energy management and negotiated agreements have been implemented since late 1970s. Use of negotiated agreements increased rapidly in the early 2000s, but few new program have been implemented since, as emissions cap-and-trade schemes were being developed. These trends reflects how countries first introduced negotiated agreements to promote industry's voluntary efforts and regulations for energy management as measures to give industry flexibilities in choosing energy saving actions, but then shifted towards more mandatory schemes aimed at specific targets. This shift has occurred as information asymmetries (between industry and government) about the potential energy savings and costs of technical actions has narrowed somewhat, and as the necessity of acting more decisively to abate industrial CO_2 emissions as part

(*footnote continued*)
which contains data provided by IEA member countries since the late 1990s (IEA, 2010). The numbers of past policies are probably underestimated. Relevant EU Directives were assured to have been transposed and were counted as being implemented in each individual member country. Some include integrated policy including multiple types of measures. In that case, the numbers of types are counted. Therefore, the vertical scale is not equal with the number of policies.

Table 2
Energy efficiency policies to industry in each country, as of November 2010 X: policies being implemented; E: policies ended/superseded; and P: policies planned.

	Regulation for efficiency of equipment, process	Regulation for energy management	Control retrofit/ replace	Negotiated agreements	Energy taxes	Directed energy tax reductions	Directed financial incentives —loans	Directed financial incentives—subsidy	Cap and trade scheme	Identification opportunity	Cooperative measures	Capacity building	Publicity
Australia	x	E				x		x	P	x	x	x	x
Japan		x		x		x	x	x	x	x	x		
Republic of Korea				x			x	x	P	x	x		
New Zealand								x	x	x		x	
Austria	x							x	x	x	x	x	
Belgium	x			x		x		x	x	x			
Czech-Republic	x							x	x	x	E		
Denmark	x			x	x	x		x	x	x			
Finland	x			E				x	x	x	x		
France	x	E		x		x	x	x	x	x	x	x	
Germany	x	x		x		x	x	x	x	x	x	x	
Greece	x							x	x	x			
Hungary	x						x	x	x	x			
Ireland	x	x				x		x	x	x	x	x	
Italy	x	x		x		x		x	x	x	x		
Luxembourg	x			x	x			x	x	x			
Netherlands	x			x	x	x		x	x	x			
Poland	x								x	x		x	
Portugal	x	x				x		x	x	x		x	
Slovak Republic	x							x	x	x	E	x	
Spain	x			x			x		x	x			
Sweden	x			x	x	x			x	x		x	
UK	x			x	x	x	x	x	x	x		x	
Turkey		x						x		x	x	x	
Norway					x			x	x	E		E	
Switzerland				x	x	x		x	x			E	
Canada	x					x		x	P	x	x	x	x
US		x		x			x	x	P	x	x	x	
Russia								x		x			
China	x		x	x				x		x		x	
Brazil	x									x	x	x	
India	x	x								x	x	x	x
Mexico				x			x			x	x		
South Africa	x	x		x						x	x	x	

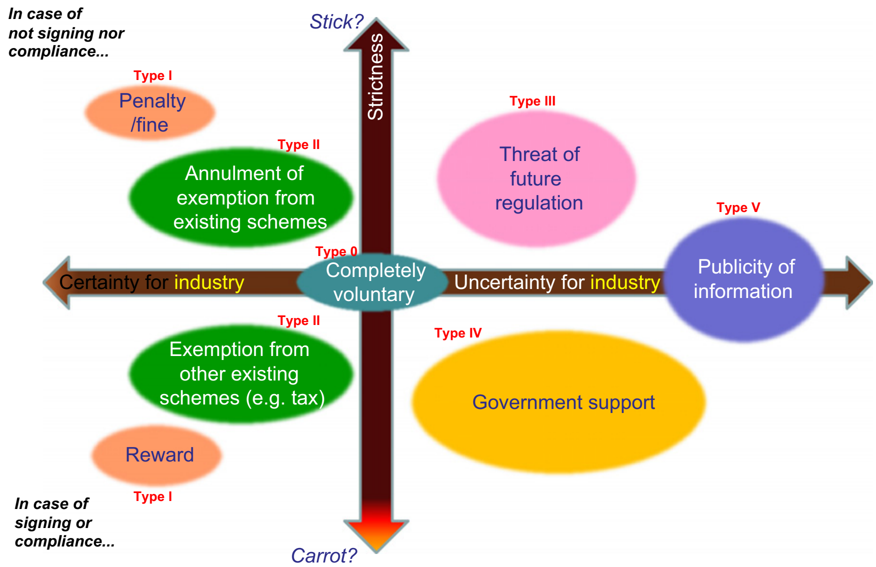


Fig. 8. Industry's incentive factors in compliance with voluntary agreement: strictness and uncertainties.

of climate change mitigations efforts has become clearer. Among economic policies, subsidies and preferential loans, often tied to energy audits, have been used since mid- and late-1970s. Carbon taxes and energy tax reductions tied to energy efficiency actions have been introduced, but have not increased greatly in popularity. In contrast, greenhouse gas emissions cap-and-trade schemes have only recently been introduced, but already account for 7% of all measures—all European countries – and are being seriously considered in other IEA countries. It should be noted that Figs. 7 and 8 indicate only general shifts in preferences for different policy types. Because policies and measures vary greatly in terms of energy savings ambition and effectiveness, such a simple enumeration of implemented measures says little about overall trends in energy savings or which policies are delivering those savings. Indeed, one major policy (e.g., an emissions cap-and-trade scheme) could have the same effect as hundreds of smaller measures.

Table 2 shows the energy efficiency policies introduced to industry in each country. It shows that a number of attempts are being made in many countries. Looking at individual polices, regulation for efficient equipment, agreement, subsidy and identification opportunity is introduced in many countries.

2. Policy review

This section includes assessment criteria (2.1) and summaries some remarkable policies and measures in each policy type (2.2). Each policy summary contains brief descriptions, examples and evaluations.

2.1. Assessment criteria

The effectiveness of the various policies and measures is situation-specific. It depends on how well they are designed and executed for their particular focus and circumstances, which vary according to:

- Technical scope—equipment, process, plant, entity, industry and whole economy;
- Circumstances—energy prices and subsidies;
- Barriers to rational energy use—companies' low priority on energy costs and market failures;
- Industrial structure—demand for manufactured products and feedstock supply;
- Policy traditions—command-and-control, technical assistance, penalties and voluntary actions;
- End goals—lower energy use and lower CO_2 emissions.

Thorough evaluation of the effectiveness of energy efficiency policies and measures would need to consider how each fits with its particular situation-specific circumstances, and how well it fits with, or complements, other policies. Quantitative ex-post evaluation requires transparent and credible information on: (1) counterfactual business as usual (BAU) baselines, (2) policy targets and (3) measured performance concerning energy use or intensity. And when policies and measures are implemented as parts of a policy package—as they often are—quantitative ex-post evaluation requires insight into each component's' relative contribution to the whole. The difficulty in comparing policies and measures across countries is exacerbated by differing methods in determining BAU baselines, as well the various situation-specific circumstances. As such, this paper does not comprehensively judge which policy among the various types is best. Rather, it shows policies' merits and demerits and the influential factors on their effectiveness, and offers some general observations on the measures' properties according to the following three performance criteria: potential to reduce energy use and CO_2 emissions cost-efficiently; ease of policy development, execution and evaluation; and ancillary effects. There is no comprehensive set of assessment criteria in exiting literatures, which is especially customized for the energy efficiency policy for industry. This paper originally provides the set of criteria.

1) **Potential to reduce energy use and CO_2 emissions cost-efficiently**

This criterion concerns how much the measures can improve energy efficiency in comparison with the non-policy, BAU situation. It depends on the measures' industry coverage, motivational power and compliance flexibility. **Industry coverage** refers to the technical potential for energy and CO_2 savings of the targeted technologies, practices and sectors. **Motivational power** refers to the degree of ambition, stringency (of rewards/penalties) and precision of the measures. That is, the extent of their ability to effect reductions in the energy and CO_2 streams associated with the covered technologies, practices or sectors. Ambition is the depth of the savings attempted; stringency is level of compulsion of the rewards for compliance and penalties for non-compliance and precision is the degree to which energy (as opposed to other policy concerns) is the primary focus. An important stringency factor is whether the intended actions are mandatory or voluntary. **Compliance flexibility** refers to the degree of industry discretion in the particular technical actions taken. It is industry's latitude in choosing the particular technical actions for complying with the measure. It is pivotal to the cost-efficiency of measures, but is a double edged sword. Greater discretion helps industry improve the cost-efficiency of its compliance actions (over that of mandatory or highly prescriptive policies). It can pursue technical actions that are more adapted to site- or sector-specific conditions. This effectively increases the resources available for energy efficiency-improving actions. However, the flexibility also gives industry the option of pursuing fewer or less ambitious compliance actions.

This criterion is important for countries which have specific targets for energy saving, especially for those countries that have made energy efficiency a high priority on their political agendas. For example, there are the EU's Energy End-Use and Energy Services Directive 2006/32/EC, which requires Member States to must adopt and achieve an indicative target for saving energy of 9% by 2015; and China's Energy Conservation Plan which had ambitions of reducing average energy consumption by 20% over the period from 2006 to 2010. This index is also essential for cost benefit analysis for policy implementation.

2) **Ease of policy development, execution and evaluation**

This is the ease and cost with which governments can develop, execute and monitor policies and estimate (ex-ante) and verify (ex-post) their results. It depends on many factors, with two of the more important being technical design convenience and quantifiability of results. These features affect governments' policymaking costs and effectiveness. The easier it is for governments to develop, justify and verify policies, the more resources are available to increase policy coverage and support activities. **Technical design convenience** refers to the extent to which policies can be designed with little need for detailed technical understanding of energy efficiency opportunities. The design of highly directed measures requires great amounts of data on technical options and their costs. These data are costly and time consuming to obtain, and the more their necessity can be avoided the better. Less prescriptive policies, which rely on industry to identify energy and CO_2 reducing opportunities, have less burdensome technical data requirements for governments. The **quantifiability of results** refers to the ease and accuracy of assessing the energy and CO_2 effects of policies and measures. This is important for ex-ante planning and ex-post verification purposes.

The transaction costs of policy administration are not so outstanding an issue, but are taken into account. At the policy implementation stage, questions always arise between transaction cost versus securing amount of saving energy and coverage which is related to matter of stringency and compliance. In policy development stage, the cost of governments' pre-recognition and understanding energy efficiency opportunities in industry can be also taken account as transaction cost. Theoretically, the effects of policies can be quantified by investigating,

- how the effect is estimated e.g. from the model (ex-ante)
- how large the effect was by the actual implementation of a certain policy in a certain country (ex-post)

With regards to the former, for example, the effect of regulation to single technology can be estimated by bottom-up simulation model, or the effect of economic policy using market mechanism can be estimated by econometrics model. Existing literatures can show them, as introduced in each following sub section of policy review. For the latter—ex-post effect, it is difficult to get quantitative information on how much energy were successfully saved through certain policies in past. This is because normally many factors influence on increase and decrease of energy consumptions. For example, most countries introduce multiple policies simultaneously, and there are often external influences such as energy prices.

3) **Ancillary effects**

Energy efficiency policies can influence not only on energy efficiency improvement in industry sector itself but also on national/regional economy through energy demand structure, revenue increase, job creations and changes, etc. There are many potential ancillary societal effects of industrial energy efficiency policies. In this paper, their effect on the acceleration of research, development, deployment and diffusion of energy efficient measures, is focused as one of the more important criteria among ancillary effects. Depending on how their incentives are targeted, measures may encourage or discourage R&D. In general, policies that prescribe the use of particular technologies discourage R&D, but help bring down costs through economies of scale. Policies that specify performance levels are more likely to encourage R&D, as there may be a variety of competing technologies that might contribute to meeting those performance levels. The above would not be decisive for introducing energy efficiency policy in industry sector. However, the contribution to R&D would contribute to energy efficiency from a long-term viewpoint. Moreover, such a long term merit is the field which policy is needed. This criterion yields only generalized information, as its significance for each country depends on their own priorities towards effects beyond energy efficiency.

2.2. Reviews: prescriptive policies

2.2.1. Regulations on equipment, process efficiency and energy management

Regulations on equipment efficiency, which commonly take the form of minimum efficiency performance standards (MEPS), are most commonly applied on products in the residential, commercial and automotive sectors. They are used less frequently in the industrial sector, where they are applied to some relatively uniform, widely used industrial technologies, such as boilers and electric motors.

There is a wide range of end-use equipment and energy consuming processes in industry. Therefore, regulations on equipment and process efficiency are targeted only at those having large energy saving potential, coupled with either (1) broad use throughout all industry, or (2) extensive use in a narrow range of industries. Otherwise, the transaction costs of evaluation, management and validation would be too large. In practice, most regulations are applied to broadly used equipment or processes, such as electric motors and boilers. MEPS most directly affect equipment manufacturers and importers—preventing them selling inefficient equipment. In many cases, the regulations are enhanced by auditing, environmental improvement of skill development, assisting identification of opportunity, or combining with financial measures. MEPS for electric motors, boilers and industrial equipments have been implemented in the European Union, North America, Australia, Brazil, China and Mexico. Standards for maximum heat loss from combustion facilities are used in Germany. (IEA, 2009b; EU, 2008a; Nadel et al., 2002; NRCAN, 2008a; Garcia et al., 2007; NDRC, 2005; Wang, 2006)

Regulations can also be used to influence full process efficiency and/or process configurations in industrial sectors. At present, they are only used in China.[5] (NDRC, 2005; Wang, 2006) More typically, governments define energy efficiency goals for specific processes, factory or industry sector, based on best domestic or international practice – enumerated as benchmark targets – through negotiated agreements or non-binding targets (see Section "Negotiated Agreement"). Another policy approach is to encourage plants and firms to employ energy management processes by regulations, such as requirement of energy manager or reporting of audit results; and setting standards for energy management, which can be seen in Japan, Italy, Canada, Turkey, Portugal and France.

2.2.1.1. Evaluation. The potential of equipment performance regulations to reduce energy use and CO_2 emissions, while high for selected products, is constrained by the rather limited number of equipment types (i.e., industry coverage) for which they are suited. From a compliance standpoint, regulations are rather rigid, allowing industry little discretion to deal with case-by-case issues of technical suitability and cost-effectiveness. If the regulations directly prescribe the use of energy efficiency related equipment or processes, they may disrupt industry's priorities concerning manufacturing techniques. For government, equipment performance regulations are relatively costly and time consuming to design and administer, especially when applied to technologies having rapid innovation cycles which force frequent revisions to the regulations. Their design and maintenance require a great amount of technical information on both the current and future circumstances of the technology and industry. To minimize these policy costs, the use of regulation is usually confined to uniform, widely used types of equipment. Because they are mandatory and apply to all purchases of particular types of equipment, and because detailed usage data is necessary for policy design, their results are highly quantifiable. Regulation's effects on R&D depend on how they are formulated. Performance-based regulations (e.g., MEPS of motors), the most common type, can encourage product R&D, because they allow for different technical means of compliance. Technology-prescriptive regulations (e.g., use of coke dry quenching in integrated steel mills) can inhibit R&D, because the market for the existing prescribed technologies is nearly assured. Technology cost reduction is the only competitive driver for R&D. The policies regulating energy management do not prescribe particular energy saving actions, but instead promote the use of energy management processes that will likely lead to technical actions. This gives industry flexibility in the choice of energy saving measures.

2.2.2. *Negotiated agreements*

Negotiated agreements involve contracts (or covenants) between industrial sectors and governments, which outline energy use or CO_2 emissions targets and schedules for industry, and compensatory support and concessions from government. Some of their features are similar to those of more aspirational, less stringent cooperative measures (or voluntary enterprise challenges and partnerships) discussed in the supportive measures section. The stringency of the energy or CO_2 targets of negotiated agreements vary, being very ambitious in some cases, and less so in others. The incentives for industry involvement also vary, but participation is usually voluntary. Because negotiated agreements typically involve targets and incentives for sectors rather than individual companies, the range of technical actions can be different (and presumably more cost-effective) among the participating companies. Negotiated agreements came to the fore in the 1990s and early 2000s, but are now being eclipsed by emissions cap-and-trade schemes in most countries. The challenge for the continued use of negotiated agreements is how they might complement emissions cap-and-trade schemes, e.g., making them more cost-efficient.

The incentives for industry involvement also vary, but participation is usually voluntary. Exemptions from other policies are the main incentive underlying negotiated agreements in Denmark, Finland, Germany, Netherlands, Switzerland, the UK and the US. Threat of future regulation, should the energy or CO_2 targets not be met, are basis of negotiated agreements in Belgium, Japan, Korea and the Netherlands. The threat of publicizing non-compliance information, thus tarnishing industries' or companies' public images, is an incentive in Japan, Swedish and US negotiated agreements.

Negotiated agreements vary in their incentive structures and have been categorized accordingly (Bernstein et al., 2007), (Price, 2005). This paper places the importance on how the policy can give incentive to the industry, or how the policy can affect the energy efficiency of the industry. Based on these points, negotiated agreements are categorized by the author based on two criteria (illustrated in Fig. 8): (1) the incentives (i.e., rewards and penalties) for signing and complying with the agreement (vertical axis); and (2) the degree of certainty that the rewards and penalties will be exercised (horizontal axis). Note that strictness and uncertainties are important factors for compliance, but cannot explain everything.

Within this 2-dimensional space six categories – one completely voluntary and five having some policy-induced incentives for action—can be identified.

- **Type 0: Agreements that are completely voluntary (blue oval).** This type has no tangible 'stick' or 'carrot' incentives. There is great uncertainty about the effects of the agreements, but no uncertainty about the nature of the incentives for industry.
- **Type I: Agreements with certain penalties/rewards (orange ovals).** This type includes penalties or rewards and promotions, which would cause certain harm or benefit to industry. In China, top 1000 enterprise scheme affects promotion and salary.
- **Type II: Agreements with annulments/exemptions from existing measures (green ovals).** This type is tied to preferential treatment with respect to existing or new policies. It awards preferential treatment (e.g., exemption from taxes) for signing the agreement and achieving its targets, or rescinds it if the targets are not achieved. Because of the ties to other policies, this type is usually introduced as part of a policy mix. The financial effect to the industry is relatively uncertain compared to that of the clear Type I penalties and rewards.
- **Type III: Agreements with threat of future regulation (pink oval).** This type is tied to preferential treatment with respect to future policy, perhaps a costly regulation or tax. As with Type II, preferential treatment (e.g., exemption from future regulation) is awarded for signing the agreement and achieving its targets, or rescinded if the targets are not achieved. Uncertainty is high, because the details of the future policy are unknown, as are the government's long term ability to give preferential treatment or follow through on the threat as the case may be. The government only has to commit "new policy will not be introduced", so administrative cost is low compared to Types I and II, but appropriate response is required in case of non-compliance.
- **Type IV: Agreements with government support for actions the targets (yellow oval).** This type involves back-up from the

[5] For example, cement plants may be required to attain certain overall benchmark efficiency levels, or iron and steel plants may be required to use coke dry quenching processes.

government to achieve the targets. The support includes recognition, awards and financial support for energy management, capacity building, opportunities identification and technical information communications through seminar and site visits by experts.

- **Type V: Agreements with publicity recognition of compliance or non-compliance (violet oval).** This type involves public disclosure of sectors' or companies' compliance or non-compliance with the targets.

Table 3 shows existing negotiated agreements categorized according to the types described above. The most common are Type II, and many have features of two category types.

2.2.2.1. Evaluation. The more successful programmes are typically those that have either an implicit threat of future taxes or regulations, or those that work in conjunction with an energy or carbon tax, such as the Dutch Long-Term Agreements, the Danish Agreement on Industrial Energy Efficiency and the UK Climate Change Agreements. Negotiated agreements vary in their effectiveness. In the IPCC Fourth Assessment Report, Bernstein et al. (2007, Chapter 7) identify the above three agreements as being successful, by virtue of having sufficient government support, often as part of a larger environmental policy package, and having a real threat of increased government regulation or energy/GHG taxes if targets are not achieved. Various researchers have found that such programmes can provide energy savings beyond BAU and are cost-effective (Bjørner and Jensen, 2002; Price, 2005; Future Energy Solutions, 2004 and 2005; Phylipsen and Blok, 2002). The first generation of the Dutch long-term agreements for industrial sectors, which ran until 2000, improved energy efficiency by 22.3% in ten years (SenterNovem, 2007). The Federation of German Industry (BDI) published the Declaration of German Industry on Global Warming Prevention (DGWP), in 1996, which expressed the industry's willingness to undertake efforts on a voluntary basis in order to achieve a reduction of 20% of the total industry's specific energy consumption by the year 2005 (base year 1990) (Ramesohl and Kristof, 2001). The Finnish Ministry of Employment and the Economy has had an industrial sector energy conservation agreement scheme with a few industrial companies since 1993. The goal of the newest energy efficiency agreements 2008–2016 is that the agreement scheme would as such cover 60–90% of the energy usage of the industrial and private services sectors. The intention is to have at least 70% of the energy usage of medium-scale industries included. An indicative energy savings target of 9% is set to each sector joining the agreement scheme, and the basic assumption is that each company joining it sets itself an indicative energy savings target of at least 9%. (Finland, 2007; MEE Finland, 2007) Sustainable Energy Ireland's (SEI) Energy Agreements were formally launched in May 2006, intending to support annual 1% cuts in national energy consumption above BAU from 2008 in line with the new EU directive on end-use energy efficiency (IEA, 2010; SEI, 2008a). The South Korean Ministry of Knowledge Economy has managed the Voluntary Agreement since 1998. A company in the scheme should submit a concrete action plan specifying its voluntary targets of energy consumption reduction and will be offered low-interest loans and technical support. (MKE, 2008) China's Top 1000 Industrial Energy Conservation Program is a negotiated agreement between the government and the private sector to reduce the energy consumption of its largest industrial consumers covers 1008 enterprises from the metallurgical industry, petrochemical industry and chemical industry. The comprehensive energy consumption of China's 1000 most energy-intensive enterprises amounted to 673 Mtce (19.7 EJ) in 2004, accounting for 33% of

Table 3
Summary of type of existing Voluntary Agreements.
Source: (IEA, 2010 ; SenterNovem, 2007; Dutch Ministry of Economic Affairs, 2001; AERES, 2008; DEA, 2008; Ramesohl and Kristof, 2001; BMU, 2007; MEE Finland, 2008; SEI, 2008a; MKE, 2008; NDRC, 2006; US EPA, 2008.)

Country	Name	Year	Type						Target/objective type
			0	I	II	III	IV	V	
Belgium/Franders	Benchmarking Covenant on energy efficiency—Franders	2004	√			√			Benchmark and energy auditing1
China	Top 1000 Industrial Energy Conservation Program	2006		√			√		Conservation plan, energy auditing
Denmark	Voluntary Agreements Industry on energy efficiency	1996			√				Energy management, investigation and investment
Finland	Energy conservation agreements for the industrial sector	1993, 1997 and 2007			√		√		Saving amount, energy auditing and conservation plan
France	Voluntary Agreement with industry to reduce GHG emissions and conserve energy	1996, 2002		√2					Benchmark and saving amount
Germany	Declaration by German Industry on global warming prevention	1996			√				Benchmark and saving amount
Germany	Integrated Energy and Climate Change Program	2007			√				Energy management
Ireland	Energy Agreements Program	2007					√		Energy management
Japan	Keidanren Voluntary Action Plan by industry	1997	√			√			Benchmark and saving amount
Republic of Korea	Rational Energy Utilization Act—KEMCO Establishment	2002	√			√			Saving amount
Netherlands	Benchmark Covenant	1999			√	√			Benchmark
Netherlands	Long Term Voluntary Agreements for energy efficiency (LTA, LTA2, MJ3)	1989, 2001, 2008			√3		√		Benchmark
Spain	Action Plan 2008–2012	2008		√					Saving amount
Sweden	Long term agreement on energy efficiency (EKO energy)	2001					√	√	Conservation plan
Switzerland	Voluntary Agreement with industry under the Law on the reduction of CO_2 emissions	2002			√				Saving amount
Turkey	Support scheme for energy efficiency in industry	2008		√					Energy intensity
UK	Climate Change Agreement	2001			√				Benchmark and saving amount
US	Climate Leaders	2000	√					√	Saving amount and energy auditing
US	Energy Policy Act (Voluntary Agreements and Recognition for Energy Management)	2008			√		√		Benchmark

Notes: (1) Obligation of energy audit; (2) if the company has excess of the GHG emission over the target, it has to procure credits from other company which meets targets; and (3) the procedure for obtaining an environmental permit is simpler for those that have. (Dutch Ministry of Foreign Affairs, 1999).

national energy consumption and 47% of industrial energy usage. Price et al. (2008) projected that the growth of 12 Mtce in savings per year over the previous year is assumed to continue through 2010 from scenario results in Top-1000 Program. Energy savings by this program would be 220 Mtce in 2010 and reducing total energy use of the Top-1000 enterprises in 2010 to 796 Mtce, which almost equal to actual use in 2006. US Department of Energy (DOE) is authorized to form negotiated agreements with industry sectors or companies to reduce energy use per unit of production by 2.5% annually from 2007 through 2016.

Researchers have reviewed the effectiveness of negotiated agreements and found mixed results, in part because of the diversity of these measures. The OECD (2003), from a theoretical standpoint, points out that "while voluntary approaches cannot compete with environmentally related taxes or emissions trading systems in terms of economic efficiency, they can do better than traditional 'command-and-control' regulations [i.e., that prescribe the use of particular technologies or practices], in particular as they can provide increased flexibility in terms of how a given target is to be met." Morgenstern and Pizer (2007b, p.182) evaluated the effect of negotiated agreements in several countries, such as Japan, UK, Denmark, Germany and the US, and found that they saved less than 10%, typically about 5%, of BAU energy use. The researchers concluded that "[…] when the arguments for mandatory programs are unclear or lacking legal or political support or where such programs will take considerable time to implement, voluntary efforts can play an important role," but that the lack of truly convincing evidence of dramatic environmental improvements makes "it is hard to argue for voluntary programs where there is a clear desire for major changes in behavior."

Even evaluations of single agreement report uncertainty about their effects. Neelis et al. (2007) showed "still substantial differences exist between the development of the energy use according to the [Dutch] LTA-1 monitoring reports and the publicly available energy statistics, resulting in different and higher efficiency improvements estimated in the LTA-1 compared with" their study based on these statistic. They considered the differences cannot be further assessed because of confidentiality of underlying data used in the LTA-1 monitoring.

In summary, negotiated agreements vary considerably in their potential to reduce energy use and CO_2 emissions, as there are big differences in their industry coverage and motivational power. The variations in motivational power of negotiated agreements are especially pronounced, stemming in part, from large differences in the strength and the certainty of the compliance among the agreements. If the motivational power is indeed strong enough to elicit significant technical actions, industry's flexibility in compliance methods helps ensure those action are cost-efficient. For governments, the design of negotiated agreements requires a great amount of detailed technical information. Furthermore, negotiations can be made cumbersome (i.e., costly) by variations in the interests of companies participating in the agreements. In addition, a credible data reporting and analysis system is needed at the compliance monitoring and verification stage. The energy savings or CO_2 reductions of negotiated agreements are reasonably quantifiable in any given country, but comparisons between countries are difficult, because of differences in BAU baselines and assessment methodologies. Negotiated agreements do not have an especially strong effect on long-term R&D, except in cases where R&D activities are stipulated in the contracts themselves.

2.2.3. Economic policies

There are two ways – carrot and stick – in economic policies used as policy for industrial energy saving. The carrot (1) is e.g. taxation and cap-and-trade schemes, and the stick (2) is giving favorable tax treatment and financial incentives such as subsidies.

2.2.3.1. Energy taxes and emissions cap-and-trade schemes. Countries impose taxes on energy, and in a few cases CO_2 emissions, to raise revenues and encourage energy efficiency and fuel switching. Taxes should encourage energy efficiency in all industries, but are presumed to be more effective in energy-intensive industries where energy is a greater share of total costs. These industries, however, can receive general reductions (in the form of credits or exemptions) in energy or CO_2 taxes, because of their effects on the industries' international competitiveness.

Emissions cap-and-trade schemes (ETS), which are functionally similar to CO_2 taxes, are being increasingly used to reduce the CO_2 emissions of industry. These measures can have great influence on industrial energy efficiency, but they do not necessarily lead to energy efficiency improvements. The objective of these policies is emission reductions, not energy savings. In many cases, actions taken to reduce emissions also result in energy savings. In other instances, however, energy is not necessarily saved. First, carbon reduction through fuel conversion—shifts from high carbon content to low carbon content energy sources—is not the same with energy efficiency. Second, carbon capture and storage reduces emissions, but the facilities require additional energy to operate.

2.2.3.1.1. Energy and CO_2 taxes. Two types of energy and CO_2 tax policies are used to improve industrial energy efficiency. The first is the taxation of industry's energy use or CO_2 emission streams; the second is the granting of tax reductions to companies engaged in certain energy saving efforts. The latter are discussed along with subsidies and preferential loans in the next section on directed tax reductions. They should not be confused with general (i.e., non-directed) tax reductions, granted in many countries to ease industry's burden in order protect international competitiveness, which lower the overall effective tax rate and discourage energy efficiency.[6]

All IEA countries tax fuel and/or electricity with VAT and excise duties; Denmark, Finland, the Netherlands, Norway and Sweden, Switzerland and the UK also have taxes on the CO_2 content of energy. Not all tax schemes were introduced to address energy efficiency or environmental concerns. Revenue from energy/carbon taxes amounts to 2–7% of country's total taxes revenue. The effective share of energy taxes to total energy costs for industry of OECD countries and of fuels are around 5–15% with some around 30%, and a few exceptional cases of more than 40% (IEA, 2007b). On the other hand, some countries have very low or no taxes for some fuel sources.

2.2.3.1.2. Emissions cap-and-trade schemes. ETS give similar energy saving and CO_2 reduction signals as CO_2 taxes, but differ in that as their signals are more volatile—depending on politically determined allowance allocation methods[7] and carbon market fluctuations. This volatility raises the risks of energy efficiency

[6] General tax reductions (in the form of exemptions and credits) are used, for example, in: Sweden, where manufacturing industries pay only 50% of the normal CO_2 tax rate; Denmark, where the CO_2 tax rate for medium and highly energy-intensive industries are 12 and 3 EUR per ton CO_2, respectively, while the rate for the households is 80 EUR (Ekins and Barker, 2001); Australia; Canada; France; Germany; Japan; the Netherlands; Switzerland and the UK.

[7] For example, let us consider that the 100% auctioning of emission allowances is proposed for the power generation and exemption or a gradual transition towards full auctioning for the other industries. In this case, power generation by waste gas in industry is also taken as power generation, which needs to be auctioned. Therefore, this is meant to avoid undue competition to the power sector, but poses disincentives, to industries, for application of wasted heat from production processes for on-site power generation. When the electricity price fully reflects carbon prices in market, industry would have incentives to use waste gas. But both the market price and whether power company transfer the cost to the electricity price are uncertain.

and other investments, especially for short-term capital turnover, above those corresponding risks in a tax-based system.[8] ETS also typically have a narrower coverage of sectors (e.g., usually only energy-intensive sectors) than taxes. At the moment, however, ETS are much higher on the political agenda, in a wider range of countries, than either energy or CO_2 taxes. Emissions trading gained particular attention as one of the flexible mechanisms to achieve the targets under Kyoto Protocol. Currently, ETS are operating in the European Union (all EU member countries), Norway, Switzerland, some US States as well as New Zealand, being developed in Australia as well as on an economy-wide scale in the US, being considered in Canada, and being voluntarily introduced in Japan and Korea as of November 2010. Early experiences of the existing schemes suggest that emissions trading is successful in reducing emissions in a cost-effective way (cf. Ellerman and Buchner (2005–06)).

2.2.3.1.3. Evaluation. Most companies are sensitive to costs, but those in some industrial sectors are more sensitive to energy and CO_2 taxes and emissions pricing than others. For example, Davidsdottir and Ruth (2004) stated through their model study of the US paper and pulp industry in US that taxation "will gradually increase energy efficiency", but "it is unlikely that an increase in energy taxes will permanently increase the industry's aggregate energy efficiency since energy cost is not seen to have significant impact on gross investment and thus on the turnover rate of capital." The reasons given were: (1) energy expenditures are small proportion of the total production cost, (2) cost of equipment installation is much higher than the energy savings gained and (3) industry requires a maximum of three year payback period on energy saving equipment. In other words, the effect of taxation is expected to be limited when these three situations apply. Johansson (2006) concluded in his paper on climate policy instruments for industry that "flat carbon taxes and ETS can lead to efficient emission reductions but might impose unacceptable costs on some industries. Other systems, such as taxation with special reductions rules for energy intensive consumers, will be environmentally inefficient as the marginal cost of CO_2 emissions is reduced to low levels." Model study estimation on the effect of carbon and energy tax in New Zealand reports that 13% of the energy consumption of fossil fuel would decrease when an introduction of tax system assuming tax revenue of 0.6% of GDP. On the other hand, the GDP decrease is estimated to be 0.38% by the decrease of the investment (0.51%) (Scrimgeour et al., 2005).

In summary, the key features of energy taxes and ETS underlying their success are comparable. Their potential to reduce energy use and CO_2 emissions cost-efficiently is high, because generally they have wide industry coverage, strong motivational power and allow a great degree of compliance flexibility. Both are, however, somewhat compromised by tax exemptions for specific industries and/or energy sources for competitiveness concerns, and the application of emissions cap-and-trade schemes, in their initial phases, to only energy-intensive industries. Furthermore, even in countries where emission trading systems are in place or considered, their coverage usually misses small and medium enterprises: for these too, a transition to lower energy use must be engineered, and existing policy tools may bring interesting lessons. It is fair to say, nonetheless, that none of these policies have been about driving transformational changes in activities, which is the purpose of more macro-economic approaches like emissions trading. Both measures have potentially strong motivational power. Designated companies are obliged to pay taxes and participate in emissions cap-and-trade schemes, and the financial incentives inherent in the tax rates and carbon prices can be substantial. Also, the rates and prices can be adjusted relatively easily in order to balance competing policy goals. The compliance flexibility is high, as the measures do not prescribe the use of particular technologies or practices. And since the motivational power (i.e., legal obligation) is so strong, the compliance flexibility is directed at improving cost-efficiency, and not at compliance avoidance. With regard to policy design, certainly a large amount of analysis and policy coordination is necessary, because the potential effects on energy use, CO_2 emissions, compliance costs and international competitiveness are so great. However, detailed technical data on each technology is not as crucial as it is for more prescriptive policies. The savings of energy and CO_2 are difficult to quantify precisely, because the true extent of the potential energy savings and their costs throughout the wide coverage area are unknown. In general, the costs of energy savings or CO_2 reduction actions, but not their effects, are easy to estimate for taxes; and the CO_2 effects, but not energy effects or costs, are easy to estimate for emissions cap-and-trade schemes. However, there still remain the difficulties of determining BAU baselines and of understanding the relationship between CO_2-based incentives and energy efficiency improvements. By increasing of the costs of using energy, taxes and emissions cap-and-trade, industry may have incentives for further energy saving, but have fewer resources for R&D.

2.2.3.2. Directed tax reductions and other financial incentives. The industrial sector often receives general reductions from energy or CO_2 taxes, because of concerns about the taxes' effects on the industries' international competitiveness. Sometimes, however, countries tie favorable tax treatment to industry's energy saving efforts, such as meeting sectoral energy or CO_2 targets (e.g., in negotiated agreements) and making energy efficiency investments. Governments also use other, non-tax, financial incentives, such as subsidies, preferential loans and R&D funds to encourage energy efficiency investment. These lower financial risk and reduce barriers possibly occurred when industry invests in new or additional technology, especially when it has payback times longer than standard. Subsidies are very popular measures in many countries. Preferential loans or loan guarantee schemes for energy efficiency investment are used in fewer countries.

2.2.3.2.1. Directed tax reductions. Some countries give industry favorable tax treatment for its energy saving efforts. Tax reductions are linked to meeting sectoral energy or CO_2 targets (e.g., in negotiated agreements) in Belgium, Denmark, Switzerland and the UK). Tax deductions are used to offset the costs of energy efficiency investments in Canada, Japan, the Netherlands and the UK.

As was discussed in the negotiated agreements section, some Type II agreements give industry tax exemptions if they meet the targets or other provisions of the agreements. For example, reductions from the UK Climate Change Levy, the Swiss taxes and the Danish Green Tax Package are all tied to compliance with negotiated agreements. In Australia, the Fuel Tax Credit is introduced to reduce the fuel procurement costs of industry, but those with large credit amount, or large scale consumers, are required to enter the climate change program by the government. (Australian Taxation Office, 2008)

Several countries use tax measures to foster energy efficiency investment. In some cases, energy efficiency investments can be deducted from the companies' base taxable amount; in others, the investments are given faster depreciation schedules, *de facto* reducing the company's tax basis. In the Netherlands, the Energy Investment Allowance encourages companies who invest in relatively innovative energy-efficient technologies or projects of renewable energy to deduct part of their investment costs from their corporate income tax. An energy list determines which equipment is eligible for tax deduction. (SenterNovem, 2008) In Canada, the

[8] This depends on how long time frame is though. With longer commitment periods and more stable schemes, the uncertainty in the long term is reduced (IEA, 2007c). The industry company, however, usually see shorter timeframe, such as a few years, for their decision-making day by day.

Table 4
Summary of subsidy, grant and fund to industry energy efficiency projects.
Source: (IEA, 2010; FABRIKderZukunft, 2008; STDC, 2008; ECCJ, 2008; EECA 2008; AusIndutry, 2008; USDOE, 2010; DECC, 2010).

Country	Name	Year	To whom	For what/total funding
Australia	Re-Tooling for climate change	2008–	SMEs manufacturers	Improvement of their production processes, reduce their energy use and cut carbon emissions. It provides grants between $10,000 and $500,000, up to a maximum of half of the cost of each project/ AUD$ 75 M over 4 years.
	Climate Ready Program	2008–2009	SMEs businesses	R&D, proof of concept and early stage commercialization projects, in order to develop new technologies and services responding to climate change./AUD$ 75 M over 4 years.
	Factory of tomorrow	2000-	Companies, research institutions, consulting and service companies	Innovative development of sustainable technologies and innovations in production and processes; use of renewable raw materials and products and services/EUR 2.54 M for year 2000.
Belgium	Technology subsidies	1983-	Multi-sector	R&D, demonstration and commercialization of new products and processes for energy efficiency
	Support for Pre-Feasibility Studies (AMURE)—Wallonia	1990-	Private sector	Maximum is 75% of total feasibility study cost and 60% of total certification costs.
	Annual Renewable Energy and Energy Conservation R&D Tender—Wallonia	1999-	Universities, high schools and research Centers and businesses	R&D and demonstration on themes of energy savings and renewable energy production.
	Energy Fund Grants for small-scale Heat generation—Wallonia	2006-		Multi-sector. Installation of micro-cogeneration systems and high-efficiency wood-burning furnaces and heating boilers./EUR 6 M.
Canada	Program to help municipalities	1999–2002		Help the Federation of Canadian Municipalities initiate a program to help municipalities identify opportunities./CAD$ 1.6 M over three years by federal budget 1999.
	Green Municipal Funds	2000-	Municipal governments and their public and private-sector partners	Innovative infrastructure projects and environmental practices./ CAD $550 M was spent as of June 2007. The 2005 federal budget added $300 M to the existing $250 M.
	Efficiency Measures for Industry: Supporting Energy Efficiency Audits	2001-	Private sector	On-site industrial audits to identify opportunities for energy efficiency./CAD$23.6 M over five years.
	Sustainable Technology Development Canada	1999-	Private sector, research centers and institutes	Development and demonstration of environmental technologies, particularly those aimed at reducing greenhouse gas emissions and improving air quality. up to a maximum of 33% of a project's costs./ Total Portfolio Value: CAD$ 1.01 billion (Approved Funding: $ 300 M, Leveraged Funding: $ 711 M).
	EcoEnergy Retrofit incentive for industry	2007-	Industrial with fewer than 500 employees	Energy saving projects that reduce energy-related GHG and air pollution. Financial incentive of up to 25% of project costs to a maximum of CAD50,000 per application and CAD250,000 per corporate entity.
China	Subsidy in improving energy efficiency and environmental quality	2008	Industry	10 energy conservation projects which NDRC started, for example, on coal boiler, co-generation, electrical machine system./RMB 48 billion. (27 billion for subsidy and capacity building and 14.8 billion for investment).
Czech-Republic	State Program to Support Energy Savings and Use of Renewable Energy and Secondary Sources	1991–2008	Private sector, NPO, universities, and towns, municipalities	Plans for energy saving in industrial enterprises and decrease energy intensity of industrial plant. (Also it includes building energy supply sectors.)
	State Subsidy Program for energy savings in industry	1996-	Industry	Implementation of measures with lower energy intensity, the efficient use of energy losses from technological processes and the application of modern technologies and materials for energy saving measures.
	Energy Management Act	2001-		Energy conservation and to the use of renewable and secondary energy sources.
	Operational Program Industry and Enterprise: Subsidies for energy savings in industry	2004–2006, 2007–2013	SMEs in manufacturing	Energy reduction investment projects (e.g. purchase of technology and equipment for higher production capacity, reducing energy consumption and modernization.)
Denmark	Subsidies for energy efficiency	1993–2001	VAT-registered companies	Investments in energy efficient equipment and in heat and electricity production with less CO_2 emission; Energy audits; Energy management; Energy efficient design; development and demonstration of energy efficient technologies; and Information projects.
EU	Intelligent Energy Europe Program –SAVE	2002-	Multi-sector	European projects, approximately 90% of the total financial support. European events (e.g. conferences). Start-ups of local/ regional energy agencies. · Concerted action with participating countries./Over EUR 215 M for the period 2003–2006 and EUR 250 M for the period 2003–2006; EUR 50 M for 2008.
Finland	Energy Audits	1980s-	Industry	Audits, which are normally 40% of the auditing cost, to identify potential ways of achieving savings in the areas of heating, water consumption, electricity and air conditioning in industry./EUR 13.7 M.
	Energy Aid	1999-	Private sector	Energy audit, energy conservation, renewable. (up to 40% of investment)/EUR 30.2 M for 2007.
	ClimBus Technology Program	2004–2008	Companies	

Table 4 (*continued*)

Country	Name	Year	To whom	For what/total funding
				Develop products and services of internationally top-class in cost-effectiveness to reduce GHG./Total funding: EUR 70 M, Annual funding: EUR 15 M.
	EE subsidies to prioritize new technology	2006-	Sectors covered by the EU ETS	Projects involving new technology, especially for electricity conservation and not heating alternative.
France	Financing for energy efficiency investments	1980-	Industry	Energy efficiency investments.
	Funding for Energy Audits—Fonds Regionaux aux Conseils (FRAC)	1999-	Industry	Energy audit.
	Survey and Pre-feasibility Assistance: Disposition Général des Aides à la Décision	2000	Multi-sector	Survey, diagnosis, pre-feasibility study. (For industry—Diagnostics: up to 30 000 Euro. Feasibility studies: up to 75,000 Euro, maximum support levels are 50% of costs.)
Germany	Special fund for energy efficiency in SMEs	2008-	Industry (SMEs)	Grants to obtain advice and consultation regarding energy efficiency. A total of 80% of the daily fee of initial advise (up to EUR 640 per day, max. grant amount of EUR 1 280) and 60% of in-depth advise can (up to EUR 480 per day, max. grant amount of EUR 4 800).
Greece	Operational Program for Energy (OPE): Fiscal Incentives for Renewables and Energy Conservation	1994-	Industrial and tertiary sectors	Renewable energy and energy conservation, substitution of fossil fuels and electricity by natural gas.
	National Operational Program for Competitiveness II	2000–2006	Industry	Increased use of renewables and CHP, energy conservation, fuel substitution, environmental protection./Total: EUR 3 445 M (340 M for the rational use of energy).
Ireland	Support for Exemplar Energy Efficiency Projects	2009-	Private and public sector	Energy efficiency project implementation (rather than R&D, feasibility and design or demonstration). For the private sector, up to 35%, a minimum of EUR 10,000 and a maximum of EUR 100,000./EUR 6.5 M in 2009.
Italy	Energy Efficiency Co-financing	1999-	Multi-sector	Energy-environment audits in industry, high efficiency electric components (motors and drives) and appliances, low-impact innovative fuels in industry.
	Lombardy Energy Conservation and Renewable Energy Promotion	2004-	Multi-sector	Rational use of energy and for its production from renewables sources./EUR 3 M.
	Financial Law 2007 and "Industria 2015" plan	2006-	Industry and buildings	Measures for GHG reduction (for the period 2007–2009) including high performance micro-CHP electricity and heating production from small scale renewable sources; high efficiency electric engine substitutions ($>$ 45 kW)./EUR 200cM yearly
	Industry 2015: Industrial Innovation Projects	2008	Private sector and research institutions	research and development targeting both efficiency and the use of renewable energy technologies.
	Special fund to support the implementation of energy efficiency targets	2010	Multi-sector	Purchase and installation of inverters, high efficiency motors, uninterruptible power sources (UPS) and capacitors./EUR 10 M
Japan	Assistance projects for businesses' rational use of energy	1998-	Industry	Development and introduction of the state-of-the-art efficient equipment and oil alternative equipment./JPY 71.7 billion
Republic of Korea	Research funding for energy efficiency technology and CO_2 sequestration	2002-	Industry	R&D for the development of energy efficiency technology and CO_2 sequestration./KRW 38 billion.
Netherlands	SPIRIT and BTS Technology Funding, Energy Saving through Innovation (EDI) (from 2001-)	1999-	Energy-intensive industry (consume more than 0.5 PJ)	Programmes to stimulate the development and market acceptance of new technologies.
	Energy Research Strategy (EOS)	2004-	Multi-sector	Energy-efficiency in the industrial and agriculture sectors; biomass; new gas and cleaner fossil fuels; built environment; offshore wind generation and electricity grids./EUR 150 M per year.
New-Zealand	Emprove	2007-	Industry	Energy audit. Half the cost of these audits, up to $50,000. Regardless of the audit cost, grants are limited to 3% of your annual energy bill.
	Efficiency Grants for Energy-Intensive Businesses (EIB)	2007-	Industries (food, metals, non-metallic) with energy spend more than 5% of total business costs	Projects that include energy efficient technologies such as: motors; fans and boilers; variable speed drives; dehumidifier dryers; heat recovery; storage and retention; cogeneration; renewable waste product fuels and industrial refrigeration. A 40% of the capital cost with maximum of NZ$100 k for single grant.
	EECA Business: Technology Projects	2009-	Energy intensive industries	Energy efficiency and renewable energy projects which demonstrate proven technologies not widely adopted in New Zealand, and for reducing company's investment risk.
Norway	Subsidies for Energy Efficiency and Renewables	2001-	Multi-sector	Energy efficiency and renewable./NKr 280 M in the budget for 2002 (NKr 100 M used for work tied directly to energy efficiency.)
Portugal	Energy Efficiency Fund	2009-	Multi-sector	Technology-oriented projects./Initial allocation of EUR 1.5 M.
Russia	Climate Doctrine of the Russian Federation	2010-	Industry and other sectors	Technology development and deployment, including energy-efficient and energy-saving technologies as well as renewable energy technologies.

Table 4 (*continued*)

Country	Name	Year	To whom	For what/total funding
Switzer-land	Support for process optimization in industry and services	2006-	Industry, universities and colleges of technology	Heat transfer technologies, Analysis and energy optimization of process systems, Use of waste heat at low temperatures and alternative systems for generating process heat and refrigeration. A total of 20–40% of cost can be supported.
Turkey	Support scheme for energy efficiency in industry	2008-	Industry	Energy efficiency projects with a maximum payback period of five years. It covers 20% of project costs up to a maximum of TRY 500,000. For SMEs, up to 70% of the costs of energy efficiency training, study and consulting services./TRY 1 M For the investment of TRY 5.1 M, as of June 2009.
UK	Environmental Transformation Fund	2007-	Multi-sector	Funds available through other funding program, such as Carbon Trusts, Carbon Abatement Technology Demonstration Program./ £400 M for the period 2008/2009–2010/2011.
US	Energy Efficiency and Conservation Block Grant Program	2008-	Multi-sector	Energy efficiency and conservation strategy; installation of distributed energy technologies; and material conservation programs/total USD $ 3.2 billion.

Capital Cost Allowance system was adjusted to encourage investment in energy efficient equipment by an accelerated capital cost allowance deduction for purchases; this policy is accompanied by an evolving list of eligible equipments and processes (Starky, 2006). In Japan, a Special Depreciation System is used to promote the equipment that facilitates efficient energy use. The system is extended and amended every few years, and also uses a list of eligible technologies. (ECCJ, 2008)

2.2.3.2.2. Other directed financial incentives. Governments also give industry non-tax financial incentives, such as subsidies, preferential loans and R&D funds, for energy efficiency investment. These measures lower financial risk and reduce barriers when industry invests in new or additional technologies, especially when they have longer-than-normal payback times. In many cases, competitions are used to determine eligibility for funding. A call for proposal from industry is announced and the candidate investment projects—after being qualified by the government, an organization approved by the government or a group of specialists—are selected for financial assistance based on criteria concerning their contribution to energy efficiency.

Table 4 summarizes the subsidy or funding schemes implemented in IEA member countries for industry energy efficiency projects. Subsidies are widely used in Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, the EU, Finland, France, Germany, Greece, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway and Switzerland. Many, though not all, target SMEs, and are used to pay for technical actions such as audits, energy management, equipment investment and R&D.

Germany's Special Fund for Energy Efficiency in SMEs has two components: the advice component and the financing component. The advice component provides grants for SMEs to obtain advice and consulting services on energy efficiency. The financing component provides SMEs with low-interest loans for investment in energy conservation measures (IEA, 2010). In Japan, a government-affiliated financial institution provides low interest loans for funding for the introduction of energy conservation systems. (ECCJ, 2008) In the UK, the Carbon Trust runs an interest-free loans scheme for energy efficiency investment of SMEs, with loans between GBP 5000 and GBP 100,000, going as high as GBP 400,000 in Northern Ireland.

Loan guarantees[9] are also used to encourage energy efficiency investments. In France, a loan guarantee fund for energy efficiency investment of SMEs (FOGIME) was created in November 2000, with a budget of approximately EUR17.8 million, which can guarantee up to EUR244 million of loans to the private sector. This guarantee is only available for certain types of risks and investments. Eligible investments include: high performance production, use, recovery and energy storage equipment; energy efficient modifications of production processes and use of renewable energy sources. The guarantee covers medium and long-term risks (2–15 years) and insures the risk taken by the financial institution providing the loan. The guarantee covers 70% of the loan in comparison to 40% average coverage rates for other SME projects traditionally covered through other banking practice for SMEs (IEA, 2010). In the US, the mandate provided by Title XVII of the Energy Policy Act of 2005 allowed the Department of Energy (DOE) to invite pre-applications for up to USD2 billions in loan guarantees in August 2006.

In some rather exceptional cases, for example China, differentiated (or punitive) pricing is used as a reward for efficient practices, and a penalty for inefficient ones. Over and above the fact that energy-inefficient processes cost more to operate, the idea has been to further penalize companies relying on these processes by charging them an additional tax on energy use. While such a measure could prove effective, a competitive environment for these industries and full-cost electricity pricing would likely have achieved the same outcome, by pushing less efficient plants out of the market. (Price et al., 2008)

2.2.3.2.3. Evaluation. One important aspect of directed financial incentives is the issue of *who pays*. In regulations, negotiated agreements and taxes, the marginal cost of energy efficiency is basically paid by the targeted industry. However, with subsidies, preferential loans and loan guarantees, the society pays for all or part of the cost. This contravenes the spirit of the polluter pays principle of environmental policy.

The potential of directed tax reductions and other financial incentives to reduce energy use and CO_2 emissions depends primarily on the measures' motivational power—the value of the financial rewards (i.e., taxes avoided or financial inflows). The value of the rewards must be high enough to overcome part of the costs of the technical actions and all of the costs of the administrative procedures of verifying eligibility for the rewards, for the targeted industry to voluntarily undertake energy efficiency measures. Industry coverage varies, from sectoral levels (for tax reductions linked to targets) to individual technologies/processes (for subsidies). The measures can cover all industry, but the financial incentives are applied only to the industrial entities which succeed in meeting specified criteria. This voluntary aspect (i.e., the choice of participating) of the measures makes them inherently less motivating than comparably stringent regulations. Compliance flexibility

[9] Loan guarantee is the agreement by a third party to pay some or all the loan amount due in the case of non-payment by the borrower (OECD Glossary of Statistical Terms).

also varies. For measures where the benefits are tied to quantitative targets, industry has considerable flexibility in its actions; in cases where the benefits are tied to prescriptive technical measures (e.g., lists of eligible technologies), industry has less flexibility.

In designing these measures, governments do not need a great amount of detailed technical data, but do need to know the potential and corresponding costs of technical actions to be supported. Quantification of the results also depends on knowing the potential and costs of the eligible technical actions. This cost knowledge is somewhat easier to obtain for measures that prescribe a limited number of eligible actions, or when there are competitions to determine eligibility, rather than sectoral targets. The potential energy and CO_2 reductions of sectoral targets are relatively easy to quantify, but the costs of the varied measures and the necessary financial incentives to motivate them are more difficult to assess. In cases where the benefits are tied to technology-prescriptive measures, there may be positive effects on R&D in the form of learning-by-doing innovation and economies-of-scale cost reductions for those technologies.

2.2.4. Supportive policies

Supportive policies consist of informational, analytical and institutional development measures, which help to establish a favorable environment for industry to implement energy efficiency actions. They help industry see and act on its energy efficiency interests as defined by the market and also by other policies. They may be a preliminary step leading to regulations, negotiated agreements and taxes, or they may be supplementary to these other policies—enhancing and verifying their effects. Four categories of supportive measures are examined in this paper: ***identification of opportunities*** of energy saving/conservation in industry; ***capacity building*** through advice, training, information sharing and education; ***public disclosure*** of energy efficiency efforts and achievements of industry; and ***cooperative measures*** in which government cooperate with industry to promote their efforts for energy saving, and increase their capacity to do so.[10] Beyond these categories, special bodies set up by government can play important roles in supportive initiatives. A good example is the UK Carbon Trust, a body which advises business and industry on low carbon solutions including provision of best practice advice, energy audits, energy and carbon management schemes and benchmarking.

2.2.4.1. Identification of energy efficiency opportunities. Knowing the opportunities for energy saving is vital to governments in designing policies, and to industry in implementing energy-saving technical actions. Measures for identifying energy efficiency opportunities include energy use surveying (with end-use technology details) and statistics reporting, auditing and benchmarking programmes. Energy-use surveys, statistics reporting and auditing are used in most IEA countries and China. Auditing and benchmarking measures are often implemented in combination with regulations, negotiated agreements or financial measures.

In some cases, the government leads the collection of data on energy consumption or the performance of technologies. This is often due to various domestic and international statistical needs. Increasingly, statistical surveys are being carried out in a manner that highlights energy saving opportunities, with a majority of countries introducing energy auditing and monitoring in addition to basic data collection. By making industry measure and report with a view to energy efficiency, governments encourage industry to think about its own potential. In the future, it is necessary to investigate what kind of data should be prepared to assess the performance of energy efficiency.[11]

Table 5 shows the measures for identification of energy efficiency opportunities implemented in IEA countries, EU and China. Most of them are implemented by combining with supplementing measures such as regulation, agreement and financial schemes.

2.2.4.2. Capacity building. Capacity building measures include equipment labels, best practice information sharing, advisory services, decision aids and education and training. They help companies lacking the resources or interest in building their own in-house expertize to assess and implement technical actions to improve energy efficiency. Efficiency labels for manufacturing equipment (e.g., motors) are used in Canada, the EU and the US. Other capacity building programmes are used in Ireland, Germany and the US (IEA, 2010; SEI, 2008b). In some cases, capacity building is used in combination with prescriptive measure (e.g., in Portugal and Turkey) and economic measures (e.g., in Canada and New Zealand).

If management decisions are guided by short-term economics and energy costs are not a high priority, information for energy saving measures and human resources for implementing them will not be developed. Sometimes priorities change in the long term,[12] even if they are low in the short term. However, if there is no short-term demand, it is difficult for the company to foster expertize and capacity of their own for the long-term. In this case, governments can use various programs to develop such abilities. Such capacity development can occur through various means, including curricula development the importance of energy saving and providing specialised technical training for students seeking industrial careers.

In some cases, measures for capacity building are used by combining other prescriptive, economic or supportive measures. To name a few, regulation of energy management such as Evaluation of Energy Audit Reports—Management Regulations for Energy Consumption (RGCE) in Portugal, the Energy Bus Program in Turkey or, those related with subsidy system such as ecoEnergy Retrofit Incentive for Industry in Canada and Emprove in New Zealand.

2.2.4.3. Public disclosure. Public disclosure (or "public surveillance") of energy performance rankings or exemplary energy saving practices can be highly motivating, and is used in combination with other measures in Australia, Canada and the US. For example, data collection and energy auditing with systematic public disclosure is planned in Australia.

2.2.4.4. Cooperative measures. Cooperative measures, or voluntary enterprise challenges and partnerships, combine many of the aforementioned capacity building services and actions together with company action plans, commitments and aspirational targets, and sometimes financing. Cooperative measures have a high degree of two-way interaction between government and industry. Their commitments and targets are usually aspirational in nature (i.e. having no severe sanctions for non-attainment) and are usually applied to individual companies, in contrast to the targets in negotiated agreements. The more elaborate cooperative measures are used in Australia, Canada and the US (IEA, 2010; NRCAN, 2008b). The effectiveness differs by the kinds of measures are included in the program. The existence of concrete monitoring and verification actions such as auditing makes it more effective.

[10] ***Direct investment*** of government for energy efficiency equipment can be also categorized as a support policy, but is not examined in this paper.

[11] Concrete examples and discussion will be found at IEA information paper (Tanaka, 2008).

[12] Recent steep rise of energy price is one example. American Council for an Energy Efficient Economy (ACEEE) intensively discussed aiming "Improving Industrial Competitiveness: adapting to Volatile Energy Markets" as the objective of the conference on energy saving in industry. (Elliot, 2007).

Table 5
Implemented measures for identification of energy efficiency opportunities in IEA countries, EU and China.

		Year	Data collection/ reporting	Bench-marking	Energy auditing (monitoring)
Australia	*Energy Efficiency Best Practice (EEBP) Program*	*1998–2003*		x	
	Energy Efficiency Opportunities Program Act	*2006-*			x*
	The National Greenhouse and Energy Reporting Act 2007	*2008-*	x*		
Austria	*Expert System for an Intelligent Supply of Thermal Energy in Industry (EINSTEIN)*	*2007-*			x
Belgium	*Benchmarking Covenant on Energy Efficiency - Franders*	*2004-*		x (a)	x (a)
Canada	*Efficiency measures for industry*	*2001-*	x	x	x (f)
	ecoenergy for industry	*2007-*		x	
China	*Top 1000 Industrial Energy Conservation Program*	*2006-*	x (r)(a)	x (r)(a)	x (r)(a)
Czech-Republic	*Energy Management Act*	*2001-*			x* (f)
Finland	*Energy Audits*	*1985-*			x (f)
	Voluntary Energy Efficiency Agreements for 2008–2016	*1997-*			x (a)(f)
	Energy Aid	*1999-*			x (f)
	Energy Efficiency Subsidies to Prioritize New Technology	*2006-*			x (f)
France	*VA with industry to reduce GHG emissions and conserve energy*	*1996-*			x (a)
	Funding for Energy Audits - Fonds Regionaux aux Conseils (FRAC)	*1999-*			x (f)
Hungary	*Energy Efficiency Action Plan*	*2007-*			x (f)
India	*Energy Conservation Act 2001*	*2002*			X(r)
Japan	*Energy Management in Industry under Energy Conservation Law*	*1979-*	x* (r)(a)		x* (r)(a)
	Voluntary Action Plan by Industry (Keidanren Environmental Action Plan)	*1997-*			x (a)
	Energy Audits	*1997-*			x*
	Auditing, Benchmarking, and Advisory Projects for Factories	*2004-*		x	x
Korea	*Integrated Energy Policy (IEP)*	*2002-*			x (f)
Netherlands	*Benchmark covenant*	*1999-*		x (a)(f)	
New-Zealand	*Emprove*	*2007-*			x (f)
Portugal	*Evaluation of Energy Audit Reports -Management Regulations for Energy Consumption (RGCE)*	*1999-*			x (r)
	Management System of Intensive Energy Consumption (SGCIE)	*2008*			X(r)
South Africa	*Technology information and research*	*2005*		x	X(r)
Spain	*Energy Efficiency Action Plan 2005–2007*	*2005-*			x
	Energy Audits	*2007-*			x
Sweden	*Long term agreement on energy efficiency (EKO Energy)*	*2000-*	x (a)		
Turkey	*Energy Audits—the Energy Bus Program*	*1990-*			x* (r)
UK	*Carbon Trust*	*2001*		x	x
US	*Climate Leaders*	*2002-*			x (a)
	Save Energy Now Campaign	*2006-*			x
EU	*Energy Efficiency Action Plan*	*2000–2005*		x (r)(a)	x (r)(a)
	Motor Challenge Program (in SAVE program)	*2003-*	x		x
	Directive on Energy End-use Efficiency and Energy Services 2006/32/EC	*2006-*		x (r)	x (r)
	Benchmarking and energy management schemes in SME (BESS)	*2005–2007*	x	x (r)	x (r)

Note: Measures supplementing: regulation expressed by (r); agreement expressed by (a) and financial schemes expressed by (f). x* means the mandatory measures.

2.2.4.5. Evaluation. Supportive measures are usually low cost (in comparison with other measures). They are only somewhat effective as stand-alone programmes in reducing energy use or CO_2 emissions, but their key contribution is increasing the cost-effectiveness of the various other prescriptive and economic measures. The awareness, knowledge, tools and procedures that supportive measures foster in companies are the foundation upon which the prescriptive and economic measures operate. Companies need these supportive resources to translate market and policy incentives into cost-efficient technical actions; governments need these resources to better understand the opportunities and barriers to improved industrial energy efficiency and to design policies and measures accordingly.

As stand-alone programmes, the potential of supportive policies to reduce energy use and CO_2 emissions cost-efficiently is relatively low, because although they have wide industry coverage, they have little motivational power. The quantifiability of results depends on the scheme, but usually is not easy because there are no obligations to measure and report before and after energy consumption and this is implemented in policy mix. Specifically, effectiveness of identification of opportunities depends on how the data will be utilized for actual promotion of energy saving. Ancillary societal effects are generally positive—the capacity building measures foster learning and skills development; the capacity building measures and cooperative measures are means to support technological R&D.

2.3. Summary of review existing policy measures

Observations underlying the measures' success are summarized in Table 6.

3. Conclusion

Industry holds a large, highly concentrated potential for improving energy efficiency. It also faces a great diversity of options for improving energy efficiency—whose attractiveness for exploitation are shaped, not only by their technical merits, but also by site-specific energy markets, economic environments, business situations, managerial priorities and implementation barriers. Governments use numerous policies to tap this diverse but high potential source of energy savings and CO_2 emissions reductions. The paper categorized the policies and measures in the typology proposed. The categorization and assessment criteria help observation of existing energy efficiency policies for industry and preliminary discussion at policy development process. This assessment organization can be further applied for quantitative analysis with combination of policy prioritization in a country, according to the criteria proposed.

The assessment result (Table 6) provides information, which is not quantitative but inclusive for comprehensive understanding

Table 6
Summary of reviewed policies in this paper.

Criteria	Prescriptive policies			Economic policies			Supportive policies
	Regulations on equipment process efficiency; and process configuration	Regulations on energy management	Negotiated agreements	Energy taxes	Emissions cap-and-trade schemes	Directed tax reductions; other financial incentives (subsidies, loans, and R&D funds)	Opportunity identification; capacity building, public disclosure and cooperative measures
Potential to reduce energy use and CO_2 emissions cost-efficiently							
Industry coverage—Technical potential for energy and CO_2 reductions for the targeted technologies, practices and sectors	Low–medium	Low–medium	Medium–high	High	High	Low–medium	Medium–high
Motivational power —Ambition, stringency and precision of measure on coverage area	High	Medium–high	Low–high	High	High	Medium	Low
Compliance flexibility—Degree of industry discretion in the technical actions taken	Low	High	High	High	High	Low–medium	High
Ease of policy development, execution and assessment							
Technical design convenience —Ability to design policy without detailed technical understanding of energy efficiency opportunities	Low	High	Low	High	Low	Low–medium	High
Quantifiability of results—Ease of measuring the energy and CO_2 effects of policies and measures	Medium–high	Medium	Medium	Low	Medium	Medium–high	Low
Ancillary effects							
Acceleration effects of long-term R&D	Medium	Medium	Medium	Low–medium	Low–medium	Medium–high	Medium–high

of energy efficiency policy for industry. For example, the table can show policy makers hints of: appropriate policies for country-specific objectives and priority; comparison in merit and demerit between policy under consideration and other policy instruments.

The sample of policies and measures discussed in this paper illustrates the wealth of approaches in use in developed and developing countries to enhance energy efficiency in industry. A more thorough exploration also shows that policy instruments are often combined or used as alternatives (taxation with agreements, audits with financing, etc.). The best practice can hardly be identified in various national circumstances, as starting points – energy prices, market conditions – often differ, as well as regulatory culture and governance structures.

No single policy or measure fits all countries, all types of industry and all situations. First, industry is different, has different needs, and faces different challenges and barriers in improving energy efficiency in different regions and countries. Second, too few *ex-post* evaluations of policies' operations and effectiveness have been conducted to understand how policies might be gainfully transplanted to other locations and situations. Lastly, technical actions for improving energy efficiency may face multiple barriers, which cannot be addressed with one single measure, so a package of measures is needed.

Further analysis, in several areas, would be productive in helping governments design policies that are more effective in directing industry to better energy efficiency. Further study is needed of the barriers and opportunities, not only in undertaking energy saving technical actions, but also in introducing and implementing policy schemes. This study targeted a broad range of policy types and countries, and could only clarify common features. There is a need for further study of, for example, focusing on selected countries as case studies, for actual implementation of policies. There is also a need for a deeper look at policy packages—how the components complement one another, and how policy coherence is maintained to ensure overall efficacy and cost-efficiency.

Acknowledgements

The author appreciates editorial assistance for manuscript preparation from John Newman. The author would like to thank the past colleagues in the IEA: Richard Bradley, Nigel Jollands, Richard Baron, Jens Laustsen, Barbara Buchner, Jonathan Sinton, Ghislaine Kieffer, Elena Merle-Beral, Ellina Levina and Dagmar Graczyk, Paul Waide and Julia Reinaud. Special thanks goes to government officials for their help in updating policy information, especially delegates of IEA Energy Efficiency Working Party from 2007 to 2009. The author also appreciates experts for providing important information: Ruying Zhang and He Ping (The Energy Foundation); Lynn Price (LBNL); Bernhard Kohl (EUROFERR); Akira Komatsu (JX Nippon Research Institute) and Hidefumi Katayama (IGES).

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