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Regulatory and voluntary approaches for enhancing building energy efficiency

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Abstract

Buildings are the dominant energy consumers in modern cities but their consumption can be largely cut back through improving efficiency, which is an effective means to lessen greenhouse gas emissions and slow down depletion of non-renewable energy resources. However, the potential energy cost saving alone is hardly a sufficient incentive to investing into improvement measures, unless the cost of using energy soars. People's attitude will change with increasing concerns about the environment and sustainable development but the results remain insignificant. Surely, more effective means are needed to induce or compel greater efforts, especially to the signatories to the Kyoto Protocol. Whilst regulatory control is widely used, many believe that encouraging voluntary commitments is more cost effective in dealing with environmental problems. More researchers now favor the adoption of a well-articulated policy mix involving both regulatory and voluntary instruments. The paper describes a comprehensive literature review about regulatory and voluntary policy instruments related to building energy efficiency. Particular attention is given to the cost-effectiveness of these instruments, as reflected by the implementation experience of several countries, and a qualitative evaluation. The possibility and benefits of harmonizing governmental and private-sector schemes are discussed.

Keywords: Buildings; Energy policy mix; Economic analysis

Contents

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1. Introduction

The Third Conference of the Parties (COP-3) to the United Nations Framework Convention on Climate Change (FCCC) was held on 1–11 December 1997 in Kyoto, Japan, to negotiate a legally binding treaty to reduce greenhouse gas (GHG) emissions. The 149 signatory countries under Annex I of the Protocol committed, either individually or jointly, to reduce the total emissions of six GHGs[1] by at least 5% below 1990 levels, to be realized within the period from 2008 to 2012 [1]. The European Union (EU) collectively committed to reduce GHG emissions by 8%; the United States (US) by 7% (from 1990 to 2012); Japan by 6%; Australia by 8%; and Canada by 6% [1,2]. Given that there is little room for procrastination if the emission targets are to be met [3], most signatory countries have introduced various initiatives, including both regulatory and voluntary measures, notwithstanding that the Kyoto Protocol is yet to be ratified [4][2].

Among the six GHGs covered, carbon dioxide (CO_2) is regarded as the most important because the amount of CO_2 in the atmosphere accounts for about 50% of the global warming effect [7,8], and its concentration has been increasing steadily since measurement started in 1958 [9]. As over one third of the global CO_2 emissions are attributed to the combustion of fossil fuels to meet the energy demands of buildings [8], many energy conservation projects are targeted at reducing energy consumption in buildings [10–13].

Enforcing energy efficiency through regulatory control has the advantage that all parties concerned will be aware of the requirements, and ensures that a certain minimum level of performance is achieved across the board. However, according to the literature [14–16] such an interventionist approach only leads to moderate results, as the compliance criteria needs to be set at levels that are relatively easy to achieve so as not to incur heavy financial burdens on society. Otherwise, the building and real estate sectors would strongly oppose the legislation, or numerous violations would render legislation difficult to enforce.

Rather than using regulatory instruments, many have opined that the voluntary-based environmental approaches that came into prominence in the early 1990s can be more effective [17–19], because they offer greater flexibility for building owners in reaching targets, thereby improving their image, and is more useful to policy makers in promoting a dialogue with the private sector and to raise public awareness [17,20–22]. However, implementation experience indicates that only moderate results have been achieved through voluntary approaches whilst achievements in meeting the ambitious GHG reduction goals are limited [23,24].

Recent findings tend to favor the adoption of a well-articulated mix of regulatory and voluntary instruments [23, 25]. Besides setting a minimum standard for all buildings, regulatory controls can also augment co-existing voluntary schemes. The voluntary schemes can benefit from the increased awareness and drive towards improvements triggered by the regulations, use the regulatory requirement as a baseline for defining enhanced performance, and provide an incentive for buildings to achieve a standard above the minimum [26].

The next section of this paper describes a general review of the various policy instruments in use for reducing GHG emissions from which three of the most widely used are identified. The merits and the weaknesses of these three instruments when applied specifically to buildings are discussed in detail in Section 3. Section 4 describes an economic evaluation of the three instruments when used in isolation and in combination, and explores how these instruments could augment one another. The framework commonly used to set performance benchmarks is also reviewed.

2. Review of environmental policy instruments

The key difference between regulatory and voluntary instruments for reducing GHG emissions is that persons responsible cannot ignore the former; whereas response to the latter is optional or otherwise it is business-as-usual.

[1] The six GHG gases included in the Protocol are: (1) carbon dioxide (CO2), (2) methane (CH4), (3) nitrous oxide (N2O), (4) hydro-flurocarbons (HFCs), (5) perflurocarbons (PFCs), and (6) sulphur hexafluride (SF6) [1].

[2] Unfortunately, according to UNFCCC's press release on 18 December 2002 [5], Australia and the US have withdrawn from the Kyoto Protocol. Enforcement of the Protocol is now pending on the ratification of the Russian Federation but, according to the report of 20 March 2003 on the status of ratification [6], the Russian Parliament has still not taken action.

2.1. Regulatory instruments

Regulatory instruments are means that governments use to intervene in the market to achieve positive changes to the social, economic or environmental gains in societies. The strictest regulatory instruments are those that impose restrictions, such as on energy consumption or a ban on import, export, manufacturing and use of certain materials (e.g. CFC compounds). Violations of the requirements are subject to prosecution under relevant legislation. Imposing mandatory codes is, generally, favored by policy makers because it is a straight-forward way of restricting the behavior of people and organizations for the achievement of a predetermined policy objective [16].

Instead of setting rigid standards for compliance or imposing bans, the policy objective can be achieved by using instruments that increase the costs of those activities that cause the targeted problem. Imposing tax or levy on certain aspects of production (e.g. energy or fuel use), or on certain undesirable by-products of production (e.g. pollutant emissions or solid and liquid waste) increases the costs of production, which leads to reduced use and/or generation of the offending by-products. Energy or carbon taxes are being used in a number of countries with the aim of reducing GHG emissions. More recently, tradable permits for CO_2 emission have been introduced to supplement regulatory controls to maximize economic efficiency in the use of resources in meeting the emission targets [27].

2.1.1. Mandatory codes

Use of mandatory codes for controlling energy use in buildings emerged in the mid-70s [28], and is by far the most widely adopted means for enhancing building energy efficiency, having been adopted in over 30 countries and regions including some developing economies like China, Taiwan and Argentina [8,29,30]. Studies of energy codes, however, indicate that they are unable to lead industry towards significantly higher standards [14–16,31]. The application of mandatory codes to buildings is discussed in Section 3.

2.1.2. Carbon/energy tax policy

The use of taxation was first advocated in 1920 by a prominent economist, Professor A C. Pigou of Cambridge University, to solve the problem of smog over London. Taxation became a key tool that social welfare economists used to deal with the problems of divergence between private and social costs (e.g. pollution) until the Nobel laureate, Professor R. H. Coase, published 'The Problem of Social Cost' in 1960, pointing out that clear delimitation of private property rights and transaction costs are the key issues to solving such problems [32–34]. The emphasis on transaction costs has since made a profound impact on public policy making worldwide, including those for addressing environmental problems.

Where energy tax is used, a consumer will have to pay an amount of tax proportional to the amount of energy consumed, quantified and based on common units, such as the oil equivalent or British Thermal Unit (BTU). The energy tax is, therefore, only indirectly related to GHG emissions. The use of carbon tax links the taxation policy directly to the abatement objective. Since in addition to the consumed amount, the tax is based on the carbon content of the fuel burnt. Carbon tax was first introduced as a regulatory instrument in Norway in 1991 as a national policy for reducing CO_2 emissions, and similar policies have been adopted in many other countries [35,36].

Among countries where such taxation policies are in place, Sweden, Norway, the Netherlands, Denmark and Finland, and most recently the UK and Italy, have implemented taxation schemes that are based on the carbon content of the energy products. Austria, Belgium and Germany later introduced the energy tax, which does not consider the carbon content of the energy products. Several other countries, including Switzerland and Japan, are considering implementing an energy or carbon tax [36–40].

Many economists and international organizations regard carbon or energy tax a more cost-effective policy than other regulatory instruments for reducing CO_2 emissions [31,36]. The advantage of using this instrument is that the tax rate, and thus the marginal abatement cost, is the same for all consumers. This implies that those facing relatively low abatement costs would make greater effort, and vice versa, until the marginal abatement costs of all polluters equaled the tax rate, leading to the most efficient use of resources for achieving the emission target. Furthermore, carbon or energy taxes are revenue to the government, which will allow the government to reduce other taxes, such as sales, income, profit and property taxes, without affecting the government's budgetary position and the overall tax burden on society.

Given that a carbon tax will raise the price of fuels having high carbon content, its use will result in greater reliance on fuels with lower carbon content, which may have adverse implications on the security of energy supply for countries that rely heavily on imported energy resources [39]. The Norwegian experience showed that there was an increase in the effective price of GHG related products and an increase in the costs of emissions reduction, which can adversely affect the economic situation [35]. Varma has pointed out that the imposition of carbon or energy tax would significantly increase the overall cost of production, and would impair the competitiveness of a country as a whole [41]. Nevertheless, on the positive side, a tax or levy can encourage switching of fuel use to alternative clean energy resources and drive innovation in means to achieve carbon abatement [35,41,42].

2.1.3. Tradable permits

Notwithstanding that the Kyoto agreement allows international trading of GHG emission permits, the EU announced in May 1999 that it was seeking to impose a condition on emissions trading that at least 50% of the total GHG reduction targets should be achieved through domestic actions [43]. Because the United States consistently opposed to this restriction, the global climate negotiations in The Hague came to a halt in November 2000 [4], and this was the main reason for US's withdrawal from the Protocol.

Whilst the restriction issue relevant to international emissions trading is yet to be settled, Canada has, among others, played a leading role in the development of GHG emissions trading for internal markets. A pilot project, known as GERT Pilot [44], was launched in June 1998 by a multi-stakeholder partnership. The GERT Pilot was designed to provide all participants with practical experience in emissions reduction trading, to assess environmental and economic benefits of the mechanism, and to pave the way for a future emissions trading system in Canada. By June 1999, 910 companies and organizations had already registered on the program.

In the UK, the emission trading group was set up in June 1999 to design a UK scheme to provide firms with added incentives and flexibility to reduce emissions and energy use [41]. The scheme was introduced in conjunction with a carbon tax in April 2002. The scheme specifies that if a facility meets its quantitative target, it can claim a number of emission permits. The permits can be sold to someone else in the same or another sector. They can also be reserved for future use or transferred between the firm's portfolios of activities.

Similar to the UK scheme, a domestic emission trading scheme has been introduced for the motor industry in Belgium where tradable certificates are issued by the public authorities for each tonne of CO_2 avoided [45]. The manufacturers can then sell these certificates in the emissions market and use the revenues to offset the price of their so-called 'green vehicles'. This experience demonstrates that allowing trading of permits can provide incentives to firms that have the ability to reduce emissions below targets since they can do so at lower costs. Recently, the EU has seriously reviewed the use of tradable permits for CO_2 emissions in the power industry [27,46]. Despite the lack of development, it is reasonable to expect that a similar trading system would be applicable to emissions from operating buildings.

2.2. Voluntary instruments

Voluntary instruments for minimizing environmental impacts include codes and eco-labeling schemes through which organizations commit to make their products or production processes more environmentally friendly [22, 47]. Market forces encourage participation if compliance with a voluntary scheme or attainment of an eco-label is perceived to be of value to the end users of products (tenants or property buyers in the case of buildings). The offer of rebates to encourage participation is also widely adopted in voluntary instrument, since rebates effectively lower the cost of implementing improvement measures.

Since the early 1990s there has been a significant increase in the use of voluntary approaches to deal with various environmental problems, including GHG emissions [31]. The number of voluntary instruments in use is more than 30,000 in Japan, in excess of 30 in the EU, and the US has 42 initiatives in existence. The extremely large number of cases in Japan compared to other countries lies in that voluntary instruments are used in almost every sector, from controlling pollutant emissions from power plants to small manufacturing factories; and from the manufacturing sector to services sector. According to Hashimoto [48] this follows from the Yokohama Environmental Agreement signed in 1964 between the local governments and the industries concerned, and is an excellent example of resolving environmental issues by voluntary instruments.

Voluntary instruments may be classified with reference to the parties involved, namely unilateral commitments made by polluters, negotiated agreements made between industry and public authorities, and voluntary programs developed by public authorities [15].

2.2.1. Unilateral agreements

Unilateral agreements refer to self-regulatory actions in which a trade association initiates a public pledge to improve environmental performance. Examples of unilateral arrangements include the Responsible Care initiative of the Canadian Chemical Producers' Association, which has received a very high participation rate among European nations [49]; the 3M Pollution Prevention Pays program; and the Hewlett–Packard's Product Stewardship program [50]. However, the number of unilateral commitments is small when compared to all voluntary instruments that exist.

A unilateral agreement involves the establishment of certain principles and rules targeted to improve a firm's performance in safety and environmental protection. From the inventory of unilateral commitments in the EU, the US and Japan [22], it was found that most of the commitments were made within the chemical industry. Although the energy sector has also made a significant number of commitments, they are mostly related to safety practices in the petroleum industry, whilst few are related to building energy efficiency. The implementation experience of unilateral agreements in other sectors shows that most of the initiatives were conceived from the perspective of industry lobbying, aiming at demonstrating a proactive effort in pollution abatement to the authorities and the public, so as to avoid potential regulatory controls [51].

2.2.2. Negotiated agreements

Negotiated agreements are contracts made between the industry and the public authorities for achieving a defined target according to an agreed time schedule. The public authority's commitment generally consists of refraining from introducing new legislation unless voluntary action fails to meet the agreed target. Literature describing the use of the negotiated agreements in the EU, the US and Japan

[31] says that this is the preferred type of instruments for waste management.

In the energy sector negotiated agreements are a key aspect of national policy instruments for GHG reduction in the Netherlands, Sweden, France, Norway, Denmark, US and Japan [23,25,38,52,53]. The agreements address energy saving and efficiency, as well as CO_2 emission reduction in energy-intensive industries, mainly from firms engaged in energy generation, distribution or retail businesses [54].

Most agreements involve stringent quantitative pollution abatement targets, but such ambitious targets can only be achieved if the industry accepts a greater share of the responsibility and cost of the development and implementation of pollution abatement measures. So far, only moderate results can be observed due to the non-enforceable nature of the commitments, poor monitoring, and limited credibility due to lack of transparency. However, there is consensus that, compared to regulatory controls, using negotiated agreements incurs lower administrative and compliance costs, as the reporting and monitoring tasks can be made more flexible and less demanding [31].

2.2.3. Voluntary programs

In voluntary programs, generally known as eco-labeling schemes, participating firms commit to, or demonstrate fulfilment of standards put forward by public authorities, environmental agencies or trade associations in order to use participation or any certification for a beneficial purpose, such as image building, etc.

Environmental performance assessment schemes for building designs or completed buildings, which include energy performance assessments, are voluntary programs for abatement of GHG emissions that focus on buildings. Typically, a building is assessed with reference to a set of quantitative and qualitative performance criteria [55], and would be awarded credits when in compliance with the various aspects that the assessment covers. The threshold performance (zero credit) levels are often set at standards that correspond to the business-as-usual situation, so that attainment of credits reflects better performance in the particular aspect [26].

Energy efficiency labeling schemes, whereby products, systems, and buildings have to demonstrate compliance with defined criteria, are another type of voluntary program that is widely adopted. The major difference between energy labeling and environmental performance assessment schemes is that the former covers only the specific issue of energy efficiency, and is more often applied to consumer products.

Both types of schemes aim to provide indirect incentives to exceed existing regulatory requirements and common practices, which may also encourage innovative technological advancements or paradigm shifts in organizational objectives [20,56–58]. Therefore, such schemes are often regarded as complementary to related policy instruments, and are by far the most widely adopted instruments used to encourage the improvement of building energy performance [17].

2.2.4. Other voluntary instruments

Rebate schemes, which are often offered under demand side management (DSM) programs to provide incentives for building owners to adopt energy saving measures, are voluntary instruments that have yielded good results since the first scheme was launched in the US in the early 90s [59,60]. However, rebate schemes are not under any of the three categories of aforementioned voluntary instruments. In practice, they can be an initiative of a utility company, thereby classifying them as unilateral agreements, or arise due to a private agreement between a utility company and a public authority, thereby becoming negotiated agreements. Legally non-binding building energy codes, often omitted when voluntary instruments are discussed, are similar, as they are often used as an eco-labeling instrument.

3. Instruments for improving building energy efficiency

As seen from preceding sections mandatory requirements and voluntary programs are the major instruments being used for improving building energy efficiency. Other policy instruments are intended to ensure a country achieves its commitments on emissions. Mandatory codes that stipulate minimum energy performance criteria for buildings are commonly referred to as building energy codes. In some cases, codes originally intended for mandatory implementation, are being implemented on a voluntary basis, such as the building energy codes for Hong Kong.

Simply classifying the voluntary instruments by the nature of the parties involved will not adequately cover the many different types of schemes adopted for building energy efficiency. Some widely used voluntary instruments for promoting improvements in building energy efficiency, such as rebate schemes, do not fall exactly into any of the three types of instruments identified (i.e. unilateral agreements, negotiated agreements and voluntary programs) because they can be developed by the professional bodies, voluntary agencies, or local public authorities.

To allow a more systematic study of the various instruments used for enhancing building energy efficiency, the following classification is proposed:

1. Building energy codes that are regulatory requirements, so are legally binding;
2. Incentive-based schemes, including various schemes that provide subsidies or allowances that can offset the costs of improvement measures; and
3. Eco-labeling schemes, including those that adopt a single threshold performance rating or labels of different grade corresponding to progressively higher standards, and legally non-binding building energy codes

and voluntary building environmental performance assessment schemes.

In the following discussions, greater emphasis is put on building energy efficiency programs in the above three categories, which are being adopted in US, UK and Canada, and more recently in Hong Kong and China. The first three countries have had a long history of implementing these instruments, whereas the energy efficiency policy developments in Hong Kong and China are largely based on the experience of the former countries. This provides a contrast between the various initiatives that are at different stages of development.

3.1. Building energy codes

The US government has long been instrumental in the development of building energy codes. In the evolvement of energy conservation laws, the 1975 Energy Policy and Conservation Act (EPCA), established with the view to regulate and possibly curb energy consumption and limit the dependence on imported oil, was among the first of such laws to emerge worldwide. The Act has been amended on various occasions over the past two decades, and Title One of the 1992 EPCA provides an overview of the energy related legislation [61].

The 1992 EPCA has had a profound impact on the use of building energy codes in the United States. Under the EPCA, every state was required to certify before October 1994 that its energy codes would meet or exceed the requirements of the ASHRAE Standard 90.1-1989 [62]. At the time it was estimated that the EPCA could lead to a 20% reduction in energy use in half the new commercial buildings built during 1995-2010. Whilst it has yet to be seen as to whether or not this saving can be realized, the package of the US energy codes and the 90 series of ASHRAE Standards is by far the most widely adopted model used in other countries in the development of national energy codes.

In conjunction with federal laws and the ASHRAE energy standards, a range of approaches have been used by different States. There are standards that range in complexity from those covering only basic envelope design to much more advanced simulation-based building energy performance assessments, and embrace low-rise residential buildings as well as high-rise commercial complexes. Judging from the number of standards that have been issued in different states, California [63], Hawaii [64] and Washington DC [65] have been particularly active in this area.

In the UK the energy performance of buildings is enforced through Part L of the Building Regulations [66], the latest version of which was issued in 2002. Part L1 deals with conservation in dwellings and Part L2 with buildings other than dwellings. Compared to the 1995 edition the new document encompasses the overall building and system performance, rather than certain feature-specific requirements, with the aim to deliver real improvements in reducing CO_2 emissions through conservation of fuel and energy. The Regulations also specify compliance with the British Standards and specifies guides and technical memoranda (TM) published by the Chartered Institution of Building Services Engineering (CIBSE).

Two British Standards are specifically relevant to building energy efficiency; one on the energy efficiency in buildings issued in 1985 [67]; and another on energy efficient refurbishment of housing issued in 1995 [68]. CIBSE has also issued four building energy codes and an energy-related technical memorandum. The coverage of the CIBSE building energy codes and technical memorandum range from naturally ventilated houses to heated and air-conditioned high-rise buildings; and from the design of the buildings to the operation and maintenance of the services systems. The British Standards and CIBSE Guides, which are amended periodically in response to changing needs and technologies, are well-received by industry and are serving as practice guides for practitioners.

Canada introduced the Model National Energy Code for Buildings (MNECB) in 1999 [69], mandating energy consumption targets for space conditioning, lighting, and service water heating. Whilst experience of implementation indicates that the MNECB is only congruent with prevailing levels of good practice, only a few jurisdictions in Canada have adopted the code, with resistances from the industry cited as the major obstacle [70], but exacerbated by the sophisticated design of the regulatory package. It allows for both default minima and a simulation path for compliance, and also takes into account energy costs and incremental construction costs within a life-cycle cost formula. Demonstration of compliance requires benchmarking the design case against the reference case, both of which are to be determined by computer simulation. Trade-offs amongst different energy sources are also allowed, but justification for the energy source adjustment factors on initial costs and environmental factors are required.

A second code was also issued in Canada in 1999 mandating requirements on energy performance of houses of height less than 3-storey [71]. The compliance requirement is similar to MNECB for buildings, allowing compliance to be based on prescriptive requirements as well as performance-based requirements, with trade-offs. However, the optional compliance path involves rather sophisticated calculation procedures, which complicates implementation. These factors, together with the relatively low energy prices in Canada, have made it difficult to build a consensus for strong action in the area of building energy performance.

Similar experience is found with the implementation of energy codes in Hong Kong. The Energy Efficiency Office (EEO) under the Electrical and Mechanical Services Department of the Hong Kong Government was established in 1994 with the vision of transforming Hong Kong into a top-rank city in the efficient use of energy. A well-recognized initiative is the publication of five codes of practice on energy efficiency of buildings. The Code of Practice for Overall Thermal Transfer Value (OTTV) in Buildings [72] issued by the Buildings Department in 1995 is the first building energy efficiency code developed by the Government. The code stipulates the standard OTTV calculation method and the compliance criteria, which are the basis of the regulatory control over the OTTV of buildings, enforced through the Building (Energy Efficiency) Regulations since July 1995.

In 1998, the EEO issued three codes of practice covering the energy efficiency of lighting, air-conditioning and electrical installations in buildings, respectively [73–75]. The code on the energy efficiency of lifts and escalators was launched in 2000 [76]. The codes are collectively referred to as the building energy codes. The OTTV code may be regarded as a performance-based code, as only one single performance metric is used for demonstration of compliance while flexibility is allowed for achieving the OTTV limit through using different building envelope design features. The other four codes are based on prescriptive requirements.

Whilst the latter four energy efficiency codes were originally intended for mandatory implementation, they are currently being implemented on a voluntary basis under the Hong Kong Energy Efficiency Registration Scheme for Buildings (HKEERSB) launched in 1998 [77]. Up to May 2002, 67 buildings had registered under the scheme, and it has been estimated that a saving of 1% of the total electricity use for Hong Kong has resulted [78].

The reasons for the delay in mandatory implementation of the energy codes include:

1. The need for a performance-based code to supplement the prescriptive codes to allow flexibility in compliance and widen acceptance (the development of this new code is still on-going).
2. Unlike the OTTV code which focuses on building design and thus can be conveniently incorporated into the existing Building Regulations and put under the jurisdiction of the Buildings Department, the codes on energy efficiency of engineering services systems require a new set of regulations and a new mechanism for their implementation. This includes the establishment of an administrative arm within government; means of implementation, which includes the definition of professional persons to be made responsible and accountable for submissions; and the consequences of violations. How this could best be dealt with is yet to be worked out.
3. There are resistances from the local building industry, and some professional bodies; e.g. the Hong Kong Institution of Architects, preferred voluntary actions rather than regulatory control.

The above indicates that the acceptance levels and the effects of both the legally binding and non-binding building energy codes of Hong Kong remain unattractive and much needs to be done if more significant gains are to be achieved.

Energy policy instruments in the People's Republic of China are rather complicated. Many types of laws and codes for buildings have been introduced since 1986, including provincial and national initiatives. At present, there are two major types of building energy codes in mainland China, namely GB and JGJ Standards. GB Standards are national standards issued by the State Technology Supervision Bureau (STSB), whilst JGJ Standards are industrial standards issued by the China Academy of Building Research (CABR). They are both mandatory codes enforced by the Ministry of Construction.

The codes are targeted to improve the energy efficiency of hotels and in residential buildings. The code for hotels, GB 50189-93 [79] was developed primarily for tackling the rapid growth of heated and air-conditioned hotel buildings. The residential code JGJ 26-95 [80] applicable to new buildings places emphasis on the avoidance of excessive heating energy to counter poor envelope performance and low efficiency methods of heating. In 2001 CABR issued three codes of practice for the energy efficiency of heated and air-conditioned residential buildings, renovated residential buildings, and inspection of heated residential buildings [81–83]. The target is to achieve 50% energy saving by 2010, including 20% from improved thermal insulation and 30% from better building systems and management.

Other than the mandatory codes there are design codes which serve as enabling instruments to enhance building energy efficiency. Guidelines are given on the design and selection of building envelope, lighting, heating, ventilating and air-conditioning installations, and electrical systems [84]. Although the energy codes in China have been developed over two decades, there seems to be no published information as to their effectiveness or whether they have been well received by the industry.

It has been often stated in the literature that legally binding building energy codes can be effective only if they are properly enforced, and define a business-as-usual level of performance, which is supported by the implementation experience in Canada and Hong Kong. Relying on the mandatory codes to curb energy consumption in buildings will continue to be rather ineffective. Energy codes without regulatory support, even when well-received by industry, provide little incentive for meeting reduction targets.

3.2. Incentive-based schemes

Increasingly since the late 1970s power companies have launched DSM programs [85] to influence consumers on the amount or timing of electricity use, so that the efficiency of generation plants could be maintained, the capital expenditure on new generating equipment postponed, and impacts on the environment minimized [86]. The objectives of a DSM program may include peak clipping, valley filling and load shifting [87]. Peak clipping can be achieved by reducing the overall consumption or simply cutting back demand during peak periods; valley filling encourages electricity use during off-peak periods; and load shifting discourages consumption during peak periods and encourages consumption during off-peak periods. The major means to achieve the DSM objectives is the use of differential tariff rates for different time periods in the day.

Power companies have interest in promoting valley filling and load shifting measures as they allow the sale of more electricity but with less capital investment for generation plant. However, valley filling will not, and load shifting may not, lead to reductions in energy use. In DSM programs initiated by public policy makers seeking to improve energy conservation, environmental protection or sustainable development, peak clipping through energy saving measures is preferred.

Rebates are usually offered in DSM programs to provide incentives to adopt energy saving measures [59]. US utilities launched the first rebate-based DSM program in the early 90s, which was well received and has provided significant savings [59,60]. Since then, a number of utilities in various countries have introduced similar programs, usually targeting the use of energy efficient lighting fixtures, air-conditioning and heating systems [88,89], and through which considerable electricity savings have been achieved [90,91].

In Hong Kong, two private sector power companies, the China Light and Power Co. Ltd (CLP) and the Hongkong Electric Co. Ltd (HEC), have the monopoly right to generate, distribute and sell electricity, each to a different part of Hong Kong. The Companies are under the scrutiny from the Hong Kong Government through a Scheme of Control, which includes an agreed basis for determining the permitted maximum annual return from selling electricity. Since, essentially, the maximum return is based on a fixed percentage of capital expenditure, the two power companies tend to encourage electricity consumption to justify expansion of generating capacity, which is obviously counter-productive to energy conservation and reductions in GHG emissions.

Nevertheless, the two companies made separate agreements with the Government in May 2000 to formulate DSM programs. The first peak clipping DSM programs were launched in July 2000 [92,93], as rebate-type programs targeted at heating, ventilating and air-conditioning (HVAC) and lighting installations in non-residential buildings. Under the lighting programs, rebates were given for the use of compact fluorescent lamps, electronic ballasts, and energy efficient fluorescent tubes. The HVAC program promoted the use of energy efficient features, but no specifications was made as to any particular energy efficient system designs or equipment. It was up to the customers to propose, for the approval of the utility companies, any energy saving measures of their choice. According to the power companies' estimates, the capacity and energy savings could be 32.8 MW and 96.9 GWh, respectively, which correspond to 0.3% of the total installed capacity and 0.23% of the total electricity consumption for Hong Kong [92,93].

Other than the rebate scheme, the Hong Kong Government put forward another incentive-based instrument in 2001 to promote adoption of environmentally friendly features in building designs, which includes balconies, wider common corridors and lift lobbies, communal sky gardens, podium gardens, acoustic fins, sunshades and reflectors, wing walls, wind catchers and wind funnels [94]. Building developments with such features will be offered discretionary allowance in permitted floor area or site coverage calculations, resulting in more saleable area. However, both the effectiveness of such features in enhancing environmental performance of buildings and the equitability of the scheme are questionable since the features it promotes are not linked to quantified performance targets [95].

In 2002 the Government commissioned a consultant to develop a comprehensive environmental performance assessment scheme (CEPAS), which is to include the equitable reward scheme [96]. CEPAS is intended to provide a common yardstick for the measurement of the environmental performance of buildings in Hong Kong, and energy performance will form one significant part of the scheme.

An incentive-based voluntary instrument developed by the Canadian Office of Energy Efficiency named the Commercial Buildings Incentive Program has yielded encouraging results [97]. The program, which started in April 1998, is set to run until March 2004. If an owner of a commercial/institutional building can demonstrate a 25% improvement over the requirements of the Model National Energy Code for Buildings (MNECB), i.e. the regulatory requirement, the reward is a sum twice the projected energy cost saving up to a maximum of C$ 80,000. About 300 projects have enrolled in the program [70], even though this amounts to less than 1% of the total number of buildings in Canada.

The C-2000 Program is another incentive-based voluntary program that has recently been introduced in Canada. The program is sponsored by CANMET Energy Technology Centre (CETC) of Natural Resources Canada [98] as a demonstration program for high-performance office buildings. It emphasizes energy and environmental performance of buildings, covering more than 90 technologies and practices. Funding can be obtained from the sponsor for projects enhancing the energy and environmental performance of buildings. So far only nine cases have successfully secured funding [99], indicating that the penetration rate is very low, and constrained by the rather sophisticated design and construction issues to be addressed in order to obtain funding.

In the US different types of tax incentive schemes have been introduced in various States. The use of coal for electricity generation is highest in the State of New York being, on average, 57% higher than other States [100].

To address this issue the New York State Energy Research and Development Authority (NYSERDA), under the New York State Energy Planning Board, was appointed to conduct a major review of the New York State Energy Plan. In December 2002 NYSERDA, in collaboration with seven other authorities, including the United States Department of Energy (US DOE), recommended offering tax incentives to promote use of alternate energy sources in transportation and in building operations.

The tax credit programs, which was developed by the New York State Department of Environmental Conservation (DEC) and NYSERDA, is administered by DEC. The one for transportation is the New York alternative fuel vehicle (AFV) tax credit program, which provides a specific tax credit of $2000 for hybrid-electric vehicles. GHG reduction potential has recently been included as a criterion for tax credit to stimulate development of new technologies. The program's operation has recently been extended to 2004. The program for buildings is the New York State Green Building Tax Credit program. The program was introduced to provide a state tax credit of $15.75 per square foot for commercial buildings larger than 20,000 square feet to support the installation of photovoltaic in new construction, and for innovative applications in existing buildings.

In China, locally made equipment and appliances are generally less efficient than those produced in developed countries. For example, a typical Chinese made refrigerator consumes 2.5 kWh of electricity per year per liter internal volume compared to 1.5 kWh for those of European manufacture. Likewise, buildings in China are similarly less energy efficient. In light of this, incentives have been in place since 1998 by discounting the investments made in improving energy efficiency of buildings from fixed asset tax calculations. Imported equipment with energy labels are also exempted from value-added import taxes [101]. As yet, the impacts of these initiatives have not been evaluated.

Offering financial incentives, such as rebates or tax discounts, to encourage the implementation of energy efficiency improvements are subsidies to end-users to implement various measures, which then reduces the cost and increases the demand for the measures. As a matter of course, the higher the financial incentives offered the greater the participation rate, meaning that such schemes can always be successful if incentives are high enough. However, policy makers are confronted with the question as to whether the overall benefit that an incentive-based instrument could bring exceeds the overall cost of the measures being promoted. The cost is unchanged even if partly paid by a firm or person and partly by the organization offering the incentive (most often the government). The subsidy may be justifiable if some of the benefits (e.g. reduction of global warming) are perceived to be beneficial to the society as a whole. Therefore, the determination of the rate of rebate or tax discount to be offered is a critical, but often a difficult step in devising an incentive-based policy instrument seeking to strike a balance between the attractiveness and effectiveness of the instrument, and the benefit and cost to society.

3.3. Eco-labeling schemes

Eco-labeling schemes emerged in the late 1980s consequent upon the increasing concern of the general public about environmental problems. It did not take long for marketing professionals to realize that declaring a product to be environmental friendly could expand market share [20,56, 57,102]. Although there is little consensus amongst the scientific community as to what qualifies as a green product [103,104], the number of products claiming environmental benefits more than doubled between 1989 and 1990 [57]. Since the early 1990s, the trend of attaching eco-labels to manufactured products also spread to building assets.

The two major types of eco-labeling schemes for buildings are the voluntary environmental assessment schemes and energy labeling schemes. The former typically rates performance by overall grade, covering a wide range of building environmental aspects on global, local and indoor scales, with energy assessments forming a substantial part of the overall assessment. Energy performance under building energy labeling schemes is assessed against a benchmark defined by the requirements of existing regulations [26].

The first building environmental assessment method, BREEAM, launched and operated by the Building Research Establishment in UK, came into prominence in the early 1990s [105,106]. It is the best-known scheme and has embraced 15–20% of the new office building market in the UK [70]. BREEAM has also been taken as a reference model when similar schemes were developed in Canada, New Zealand, Norway, Singapore and Hong Kong [107]. Assessment schemes developed and adopted in other countries include: LEED [108], CHEERS [109] and Green Building Program [21] in the US; and the Eco-Management and Auditing Scheme (EMAS) in the EU [110]. However, no such schemes currently exist in China.

All the abovementioned assessment schemes share the same primary objective, i.e. to stimulate market demand for buildings with improved environmental performance. Recently, a second generation of assessment scheme has evolved from the Green Building Council (GBC) project [110]. The GBC project is an attempt to develop a global assessment framework, which is designed to account for the very different priorities, technologies, building traditions and even cultural values that exist in various regions and countries. It aims to facilitate exchange of meaningful information about building performance among countries and development of uniform performance parameters across countries. Currently, 17 national teams are participating in testing the scheme.

In the UK, BREEAM has motivated a superstore to incorporate all the current best practice in environmental design, with the aim to half the carbon dioxide emissions that conventional supermarket designs incur [106]. In Hong

Kong, HK-BEAM has also enjoyed a reasonably good participation level. Since its inception in 1996, 30 out of the total of some 100 Grade A[3] office buildings in Hong Kong have undergone a HK-BEAM assessment. For the 30 assessed buildings, at least five have been encouraged and have committed to make improvements to the energy efficiency of the existing installations so as to gain higher credits. Although few of the assessment schemes have made public the results of there implementation, such schemes continue to penetrate in various parts of the world, suggesting adoption to be worthwhile.

Of the energy efficiency labeling schemes, the best-known scheme is undoubtedly the Energy Star Program, which was launched in the US in 1992 and is operated jointly by the US Environmental Protection Agency (EPA) and Department of Energy (DOE). The Program was designed to identify and promote energy efficient products, and later expanded to cover building components, systems and services installations [10]. The Energy Star Program is a government-backed voluntary scheme that is well-accepted by industry. According to published data [112] the Energy Star label can be found on products in 30 different categories, including appliances, electronics, office equipment, lighting, heating and cooling systems, windows, and new homes. Furthermore, more than 600 buildings have earned the label, and the administrator of the Energy Star program is already working with organizations that represent approximately 17% of building square footage in the US. It is estimated that by year 2010, the program will lead to an overall emission saving in the building sector of 4% [10]. In recent years, EPA has licensed the Energy Star trademark to several countries, including Japan, New Zealand, Australia, and Taiwan, and to the EU, but use has been limited to office equipment only.

Many other countries have developed their own energy labeling programs, such as the Energy Efficiency Accreditation Scheme in UK since 1993 [31]; the Energy Efficiency Standards for Electrical Appliances in the Philippines and Thailand since 1993 [113]; the Energy Efficiency Labeling Scheme and Codes in Hong Kong since 1995 [74–79]; and the equipment labeling program operated under the Efficiency and Alternative Energy (EAE) Program in Canada since 1998 [114].

China enacted its first set of minimum energy performance standards for domestic appliances in 1989, which cover eight types of appliances, namely refrigerators, clothes washers, air-conditioners, electric fans, rice cookers, televisions, radio receivers and recorders, and electric irons. The standards were revised towards the end of the 90s. They were first introduced as mandatory standards but were found to be ineffective, because most products could already meet the standards and enforcement was not rigorous. In 1999, a new Energy Star-type labeling scheme was introduced in China, which was applied to refrigerators first, but was finally abandoned because few models in the market could qualify for the label. In the meantime, a project is underway to develop a mandatory labeling scheme for other types of appliances, based on the European energy labeling scheme [101].

It is observed that most countries started off with mandatory codes and gradually shifted toward the use of eco-labeling instruments, which are often conceived as complementary to the regulatory instrument, providing indirect incentives for going beyond regulatory requirements. Furthermore, the way in which quantification is made of building energy performance is often controversial [115, 116]. There remains a need for performance assessment and labeling schemes that are able to differentiate ‘good’ buildings from ‘average’ or ‘poor’ buildings in terms of their energy performance.

4. Policy mix

It is clear from the implementation experience that each of the three types of policy instrument for reducing building energy consumptions has merits and weaknesses. The limited information available is such that the relative merits and weaknesses cannot be evaluated sufficient to inform selection of the most effective instrument for a given application. A review of the selection criteria proposed by various researchers [10,17,117–119] shows that cost-effectiveness is considered by the vast majority to be the most important criteria.

In theory, comparison of the cost-effectiveness of different instruments can be based on benefit-cost analyses [120]. However, in general it is also difficult to accurately quantify all benefits and all costs associated with the implementation of an instrument. Attaching dollar values to environmental benefits often needs to be done through indirect methods, such as contingent valuation, hedonic pricing, valuation of the economic losses caused by degradation in environmental conditions, or the costs of remedial actions avoided, etc. [121]. It is even more difficult if the instrument is used to address international or global environmental impacts. Nonetheless, if the various instruments being evaluated all aim at a similar level of environmental improvement, comparison and selection can focus on the private benefits to the energy end-users, and the private and institutional costs using each instrument.

In the quantification, some transaction costs involved are also difficult to estimate with certainty, e.g. costs for performance measurement, verification and monitoring compliance, and costs incurred in prosecuting violations. This may explain why, instead of cost effectiveness, selection of environmental policy instruments is often

[3] Grade A, B and C buildings differ in the quality of facilities provided, with Grade A buildings best equipped, Grade B adequately equipped and Grade C without central air-conditioning [111].

based on expert opinions [122], despite this being subjective. As the US, UK, Canada, China and Hong Kong experience indicates, there is also a move toward simultaneous use of a mix of policy instruments to improve building energy efficiency. The Canadian experience further reflects that a well-articulated policy mix is more effective. This is consistent with analysis of others: different policy instruments sharing the same objective can augment one another [23,123], especially in lowering the overall transaction cost.

4.1. Benefits of well-articulated policy mix

The development of emission reduction strategies comprising a mix of instruments has been studied extensively [41,124,125], but most of the analyses focused on the strengths and weaknesses of various instruments when applied in isolation. In the light of the evidence available in the literature, the merits and limitations of using the three types of policy instruments, either in isolation or in combination, can be qualitatively analyzed with the aid of stylized diagrams to provide an explanation as to why and how a well-articulated policy-mix can be more effective than the use of single instruments.

Fig. 1 presents the total cost to a building owner against energy used in the building, and shows a rise to high levels at both ends of the curve. The rise in cost in the range of high energy use is due to the proportional increase in cost for the wasted energy which, in the extreme, could lead to losses in rental revenue (a cost to the building owner), since the higher running cost would need to be recovered through higher rents, resulting in reduced demand for the premises in the building. The rise in cost in the range of very low energy use level is due to the high cost of extensive improvement measures needed to realize the low consumption, with the loss in rental revenue consequent upon the drop in demand due to the high rates of rent needed to recover the costs. The actual energy use level will be somewhere between these extremes as the building owner endeavors to minimize cost in order to maximize profit. This is consistent with the Varma's analysis into the relation of the output of a firm set against the energy use within a given period, ceteris paribus [41].

The energy use level corresponding to the minimum cost point (the optimal condition) can only be achieved if the building owner has complete and accurate information about all the costs and benefits of the applicable improvement measures, and has the technical and financial resources to invest in whatever is needed to minimize the life-cycle cost of operating the building. When faced with incomplete information and uncertainties, which is a constraint in minimizing cost (hereafter referred to as the information barrier), according to the law of constrained maximization, the energy use could still be minimized, but according to a second cost curve (Fig. 1), the one that the building owner would face under all the prevalent constraints, including the information barrier.

The departure of actual energy use from the optimal level has been observed in studies on energy use in existing buildings in Hong Kong [126] and elsewhere [127–131]. In these studies, the observation made is that the energy use in

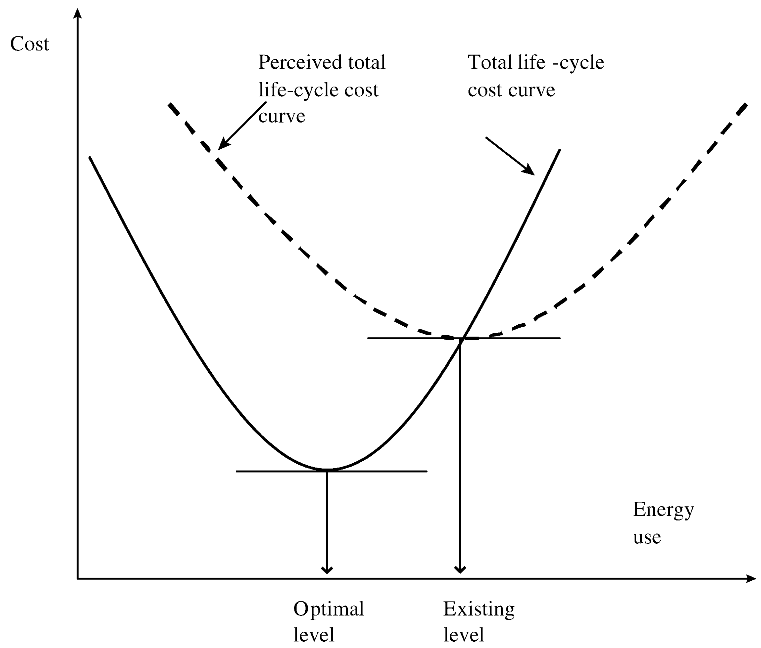

Fig. 1. Total life-cycle cost curve and perceived total life-cycle cost curve.

many buildings could be significantly reduced through the use of financially viable efficiency enhancement measures, and yet few have taken action to capture this cost saving opportunity [132–134]. This phenomenon has been referred to as the 'energy efficiency gap' [135,136].

The energy efficiency gaps are commonly ascribed to the existence of three types of barriers (most of which can be regarded as information barriers), namely knowledge barriers, motivation barriers and financial barriers [126, 135–138]. The absence of adequate yardsticks or benchmarks by which to determine the relative efficiency of a building, and the lack of knowledge and skills to identify causes of inefficiency and to devise mitigation measures, are examples of knowledge barriers. The motivation barrier exists if the potential energy cost saving is insignificant compared to rental revenue and staff cost, or when energy performance is unrelated to the remuneration of operation and maintenance personnel. The lack of a funding source for financing the required improvement measures is obviously a barrier, which occurs when insufficient reserve has been made by the building management, or no loans are available from external sources.

Fig. 2a shows the energy cost saving that a building owner could achieve by reducing energy use (assuming a fixed tariff rate), and the cost of the associated improvement measures. In accordance with the law of diminishing marginal return, the cost curve is seen to rise exponentially to reflect that the incremental return due to a further investment into improvement measures falls as more energy has been saved. The net benefit to the building owner (the energy cost saving less the cost of improvement measures), therefore, will initially rise, and then drop with further reduction in the energy use. The reduction corresponding to the maximum net benefit (the optimal condition) results as the building owner tried to maximize profit after the information and any applicable financial barriers have been removed, thereby closing the energy efficiency gap.

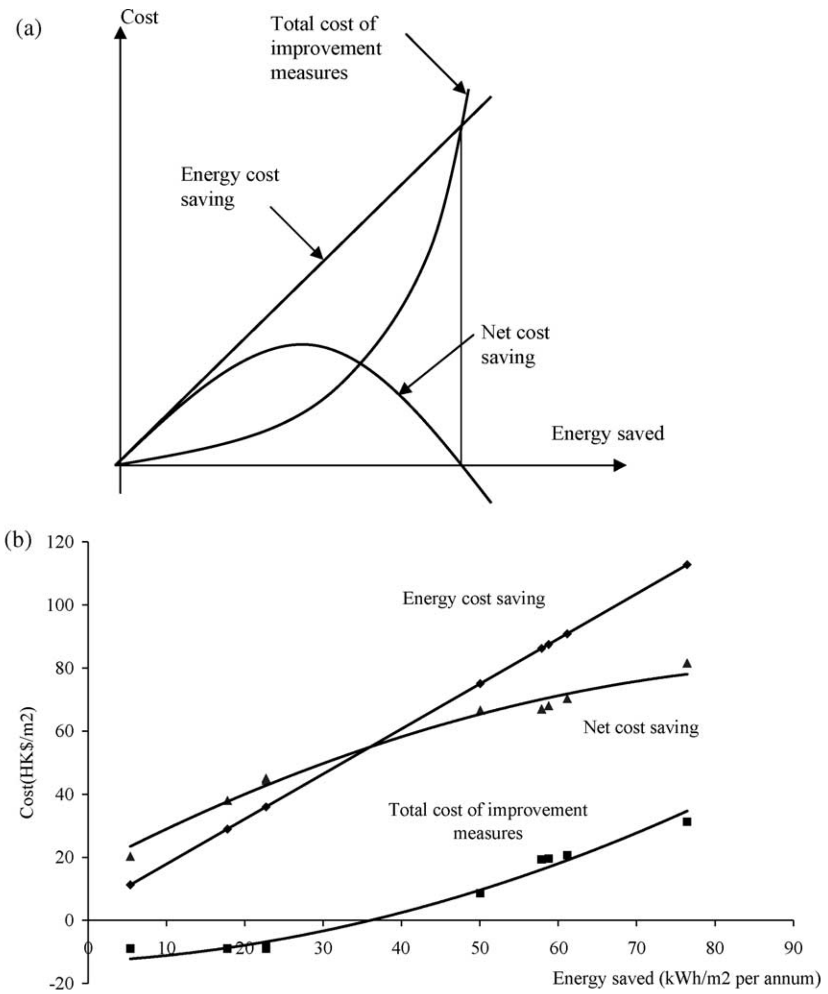

Fig. 2. Net benefit of investing into energy efficiency improvement measures: (a) a diagrammatic illustration of the theoretical implications, (b) estimated cost savings based on predicted energy saving and realistic costs of improvement measures.

Fig. 2b shows the life-cycle energy cost saving of implementing a series of energy efficiency improvement measures to a building, one after another, according to the sequential order determined based on the relative cost-effectiveness of the measures, i.e. a more cost-effective measure would be adopted before other less cost-effective ones. The improvement measures considered include use of energy efficient lamps and ballast, air-to-air heat recovery devices, smaller window area, better quality glazing, etc. The curves are similar to those shown in Fig. 2a but are based on the energy savings that the improvement measures could yield, which were predicted by computer simulation, and on the costs of the improvement measures, which were determined from actual cost data, as investigated in a separate study [139].

There is just a minor difference between the curves shown in Fig. 2a and b in that the cost curve in the latter starts from a negative value, because the first few improvement measures considered would lead to both initial and energy cost savings to the building owner. An example of such measures is the use of smaller windows, which will reduce both the construction cost and the running cost of the air-conditioning system. Although the result shown in Fig. 2b included a few measures that might not be feasible for an existing building (e.g. changing the window area), it shows that the owner of the building could derive a net gain by actually implementing the measures. This provides support that energy efficiency gaps do exist among buildings.

The above analysis implies that a win–win situation will arise when inefficient use of energy is due to the existence of energy efficiency gaps and policy instruments targeting reducing energy use can help remove the barriers that give rise to the gaps. In this respect, the command-and-control approach, such as implementing mandatory building energy codes, could be a very effective means to close energy efficiency gaps since, when compelled to make improvements, buildings with poor performance would start to realize the gains achievable from enhancing energy efficiency. Therefore, as long as the margin of energy use reduction required for compliance remained within a range in which building owners can derive net gains from implementing improvement work, the regulatory controls would receive little resistance and owners would try to ensure their buildings comply with the requirements so as to maximize profits. Under this condition, there should be little need for policing and prosecuting violations, and the institutional costs could be capped.

However, the reverse would happen if the control level was far more stringent such that compliance with the requirement would incur much higher costs to building owners, who might then tend to ignore the control unless the consequences of not doing so would be even more costly (e.g. severe fines or even imprisonment). This change in behavior to changes in financial implications on those affected is evidenced by Atwood's analysis on a group of wheat farmers responding to tightened safety rules [140]. It seems reasonable to expect that in democratic societies, proposals for stringent controls would be severely criticized and may not gain support through the legislative process. This further implies that there is a limit to the extent to which a policy objective can be achieved through the use of regulatory controls. In other words, tightening the requirement that a command-and-control policy imposes is subject to diminishing achievements.

Imposing an energy or carbon tax is an alternative regulatory instrument to command-and-control for reducing energy use or CO_2 emissions. Figs. 3 and 4 show the effects of taxation on the total operating cost and improvement cost for a building. Like command-and-control, energy or carbon taxes would help close energy efficiency gaps. There are, however, several key differences between the two types of regulatory instruments. First, the institutional cost for energy or carbon tax can be significantly lower, especially when a high tax rate is imposed, as the tax can be collected from wholesalers of energy or fuels, and individuals and firms (including building owners) would respond to the consequent changes in the market prices of energy or fuels.

However, since all energy users placed under the regulatory control (e.g. buildings) are subject to the same tax rate, those who have been performing at high efficiency levels would consider the taxation unfair to them, notwithstanding that this is an advantage based on parity of marginal abatement costs [141]. As shown in Fig. 3, as a building owner responds to the increased energy cost due to taxation, any saving in energy cost achieved through implementing improvement measures will be shared between the building owner and the government. The general public may, therefore, be sceptical about whether the government's intention behind imposing an energy or carbon tax was more to increase the government's revenues than to reduce environmental impacts. Furthermore, rather than just responding to the extent required, additional improvement work that may otherwise not have been considered cost-effective would also be undertaken, i.e. there would be a dead weight loss to the society, although a greater energy use reduction could be achieved (Figs. 3 and 4).

The above analysis echoes with Varma's review of the UK Climate Change Levy (CCL) [41] and with the conclusions of several similar studies [59]. Despite its simplicity in administration and low implementation costs, Varma pointed out that the levy could adversely affect the economic growth of a country. Furthermore, it has been confirmed that neutrality in taxation, i.e. compensating the levy on energy or fuel use by reductions in other taxes, is unachievable, due to the variations in factor prices consequent upon the taxation [41].

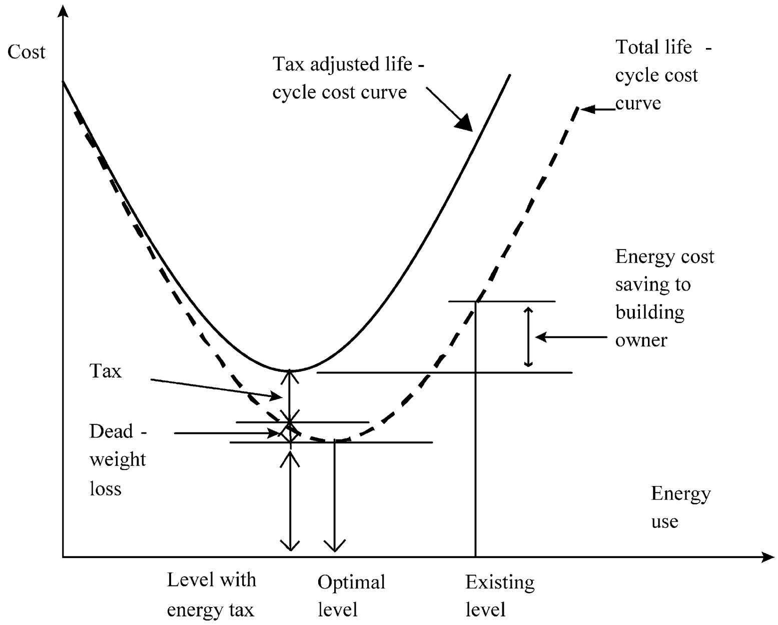

Fig. 3. Effect of energy tax on total life-cycle cost.

Since taxation is also a regulatory control instrument it shares the same constraints with command-and-control type instruments, in that it would need to gain public acceptance and only a moderate effect can be expected. Given this limitation, other types of policy instruments,such as incentive-based programs (e.g. rebate schemes) and eco-labeling schemes (including voluntary assessment programs) would be needed for achieving more ambitious environmental impact reduction targets.

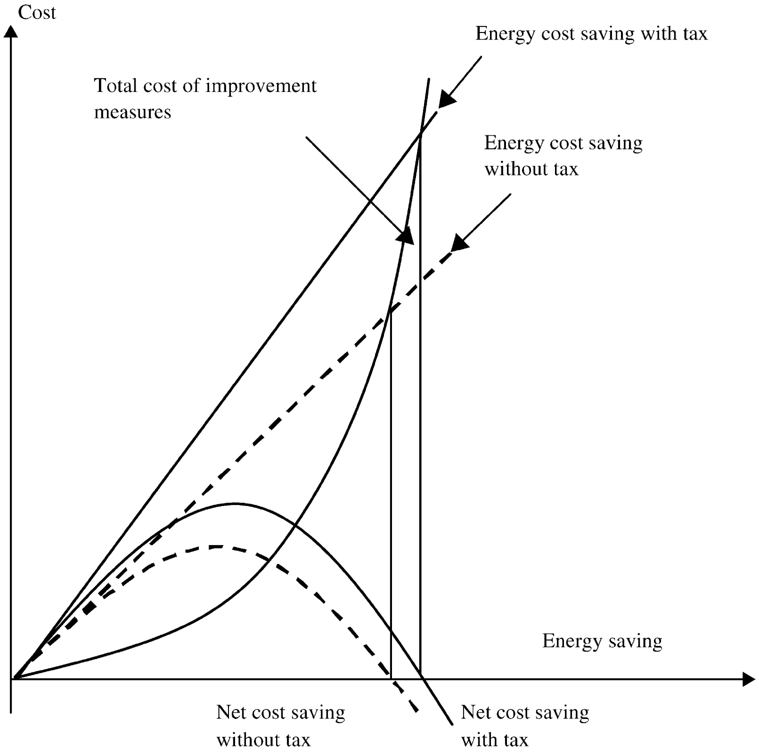

Fig. 4. Net benefit of investing into energy efficiency improvement measures with and without energy tax.

As previously discussed, an incentive-based instrument, such as a rebate scheme, can affect the choice of building owners as to whether, and how far, energy efficiency improvement measures should be taken. As already mentioned, the rebate offered is basically a subsidy that will effectively reduce the costs of, and boost demand for such measures. Fig. 5 shows the effect of a rebate scheme on the cost of improvement measures and the amount of conserved energy that results. The findings of the survey conducted for Northeast Utilities in the US on the impact of the utility funded conservation incentive is evidence of this predicted behavioral change [127]. The rebate amount that the utilities would be willing to offer would be dependent on the marginal cost of power generation and the electricity price, but such information does not reside in published literature.

All the rebate schemes in place so far are utility-sponsored initiatives intended to save the capital costs to the utility companies. However, if a rebate scheme is used by a government as a policy instrument, the funding for offering rebates would be from tax payers, which should only be used if the positive effect to society brought by the policy instrument exceeds the cost of using the instrument, including the rebate and associated implementation costs. However, whether or not offering rebates is the best instrument to use with regard to economic efficiency is a key question that needs to be addressed.

Because the costs associated with quantifying actual improvements could be high, to minimize implementation (transaction) costs the majority of rebate schemes avoid the need for performance measurement by relating the rebate to the particular energy efficient upgrade being installed, or inefficient products being replaced. As such, the link between the policy instrument and the policy objective will become indirect. The effectiveness of a rebate scheme will then be heavily dependent upon whether or not a good choice has been made of the types of products for rebate and rates of rebate. However, as discussed below, there is little chance that rebate schemes of this type will lead to the most economical use of resources.

Once particular types of products are selected for rebate, the suppliers of such products will be given an advantageous market position compared to suppliers of alternative products, or even a monopoly or oligopoly status, if there are one or a few suppliers in the market. To avoid public criticisms (and chances of corruption), such products could be precluded by policy makers even if the products are superior in efficiency. On the contrary, less energy efficient equipment could be selected due to market pressure, e.g. as a strategy for protecting local products against competition from imported products, or simply due to the need to maintain a competitive market situation. The rebate type DSM program implemented in Hong Kong is an example where there were only 20 qualifying electronic ballasts when the scheme was first introduced, but was expanded to 40 in April 2001 and to 51 in February 2003, in response to submissions from suppliers [142–145]. Whether or not all

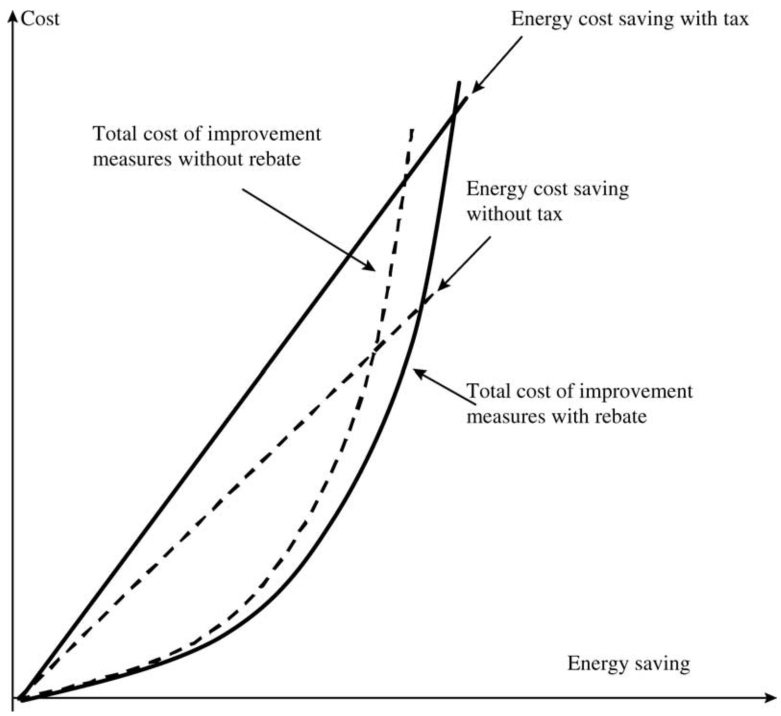

Fig. 5. Net benefit of investing into energy efficiency improvement measures with and without energy tax and rebate.

qualifying electronic ballasts have similar performance is questionable, but the same rebate rate applies.

When a rebate is given for the use of specific types of products, such products would be preferred to other substitutes, alternatives or complementary means, even if the latter could be equally or more cost-effective. For instance, if the rebate applies only to replacing conventional lamps with energy efficiency lamps, the old lamps in a building will be replaced irrespective of the fact that using the rebate money to replace the worn-out chillers could lead to more significant energy saving. However, which measure or combination of measures that would be the most cost-effective to improve the energy performance of a building differs from one building to another.

In determining the rebate rate to be offered, a proper balance would need to be sought between the rebate rate, which would have a dominant impact on the participation rate, and the effectiveness of the rebate scheme [146,147]. Policy makers may be tempted to offer higher rebate rates to boost participation, and thus to demonstrate success, but this could lead to excessive use of the promoted measure beyond an economically viable level (also a deadweight loss), such as premature replacement of existing equipment. Offering high rebate rates may also lead to inequitable transfer of public money to the scheme participants.

Where a variety of different types of products is involved, the rebate rate for each should be set such that each dollar paid as rebate for using a product should lead to the same amount of energy saving or CO_2 emission reduction. Otherwise, the benefit (energy cost saving) to cost (after adjustment by the rebate) ratios of the products would fail to reflect their relative cost-effectiveness, leading to over use of certain products beyond economically viable level. For instance, the DSM programs for energy efficiency lighting retrofits implemented in Hong Kong ceased to accept new applications well before the expiry date of the programs because the budget had been exhausted soon after the programs were launched, but much of the budget for promoting energy efficient air-conditioning installations remained in reserve [143,145]. Besides over-use of certain types of products, if realization of the policy objective relied on wider adoption of all or a variety of the promoted products, disproportioned rebate rates could lead to failure in achieving the policy objective. However, it seems that selection of a bundle of different types of products for rebate has seldom been considered by policy makers, as most rebate schemes implemented so far target the use of compact fluorescent lamps, electronic ballasts, and energy efficient fluorescent tubes [88,89].

It may be concluded from the previous discussion that using rebate schemes as a public policy instrument is prone to mistakes. Furthermore, a rebate scheme could be much more costly than a command-and-control scheme, as public money would have to be spent to gain the benefit that could be obtained through a command-and-control policy at much lower cost, especially when there are energy efficiency gaps. Using rebate as an instrument to boost performance beyond the regulated level may appear to be feasible but it would largely increase the transaction costs for differentiating measures taken for different intentions. Measures that were taken solely for satisfying the regulatory requirements would not entitle for a rebate whilst those used to achieve further energy reductions would entitle a rebate. Although combined use of energy or carbon tax with rebate schemes could lead to achievement of greater energy use reductions, as shown in Fig. 5, given that each of the two instruments could have drawbacks, simultaneous use of the two could also exacerbate the problems with each.

The command-and-control, taxation and incentive-based instruments are, to different extents, all based on market interventions. On the contrary, an eco-labeling scheme basically serves to provide information to consumers to allow them to recognize environmentally friendly products. Voluntary building environmental performance assessment schemes are alike, although the products are building premises to be sold or let. The success or otherwise of such schemes is dependent on whether the enhanced performance is valued by the consumers and whether the label can faithfully reflect the performance achieved. When these conditions are met, an invisible hand will come into play to boost production of the desired products whilst suppliers failing to respond to this shift in market demand would face a contracted market share, or even be driven out of the market. In view of the fact that the number of products bearing eco-labels of one type or another is increasing [57], it seems that some success of utilizing market forces to boost demand for environmentally friendly products has been achieved.

In a voluntary building energy performance assessment scheme, the enhanced levels of performance that it promotes need to be measured against what is perceived as basic performance. If there is co-existing regulatory control over the energy performance of buildings, the minimum performance level that satisfies the regulatory control will be a convincing basic performance benchmark readily acceptable by the public. This benchmarking strategy has been adopted in some existing voluntary schemes (e.g. BREEAM [148], HK-BEAM [149–151], etc.). The voluntary scheme and the regulatory instrument also share the need for a creditable assessment method, although the criteria for credits under the voluntary scheme will need to be higher than the minimum allowable level under the regulatory assessment. Therefore, if a voluntary scheme and a regulatory instrument are used simultaneously, the two can share the costs for the development of the assessment method [17].

Aligning the assessment method and criteria of a voluntary scheme with those of a regulatory instrument will also lead to other benefits. As mentioned above, the regulatory control can focus on closing the energy efficiency gaps leaving the role of promoting achievement of higher standard of performance to be played by the voluntary scheme. The regulatory requirements would, therefore, be readily acceptable to the industry, which would help largely cut down the implementation costs, particularly those associated with monitoring compliance and prosecuting violations.

The overall implementation cost for both schemes can also be largely reduced if the assessment result under the voluntary scheme confirms the achievement of a standard above the regulatory requirement, thereby satisfying also the requirement. This can boost the participation rates for the voluntary scheme and thus lower the running costs of the scheme. Building designers and developers will also benefit from not having to prepare two separate sets of documentations for submission. Also, if the voluntary assessment begins at the design stage, feedback on the likelihood that the as-designed performance would pass the regulatory control can be provided, avoiding the cost of the consequences of non-compliance.

If the voluntary assessment scheme embraces not only energy performance but also other aspects of environmental performance, such as indoor air quality, use of low emission and or low embodied energy materials, etc. the increased participation rate will also lead to improvements in these other aspects. When an incremental improvement to the performance of the majority of buildings has been achieved, the regulatory requirements could then be tightened, leading the whole building industry to rise to higher levels of performance.

4.2. Phased scheme

The above analysis shows that a set of well-articulated regulatory and voluntary instruments for enhancing building energy performance can be complementary to each other, and can largely reduce the transaction costs that both incur. To achieve this, the voluntary scheme requires the regulatory instrument to be implemented in advance or concurrently, as is the case with the implementation of the two types of policy instruments in most countries. Furthermore, the benchmarks for voluntary programs are invariably higher than the requirements of the regulatory instruments.

However, some research studies recommended the reverse, in both the sequence of implementation and the relative performance standards targeted [16,152]. The studies suggest that due to the scarcity of information on potential environmental improvements, beginning with voluntary instrument could be more effective, causing the least impact on the industry and lead to higher performance standards. Against this background Feijoō stated that consensus had been reached among industrialized countries in a recent conference to moderate their energy policies by strongly promoting voluntary approaches. Should voluntary instruments fail, regulatory control would still be needed, but it would then be necessarily to use stringent compliance requirements and in so doing would face strong opposition and incur higher transaction costs for implementation.

4.3. Benchmarking

The above analysis suggests that using a well-articulated mix of regulatory and voluntary instruments for achieving an ambitious reduction in the energy use in buildings would incur lower implementation costs and could lead to greater results than using a single policy instrument. Effectiveness, however, would be dependent on the minimum allowable level that the regulatory instrument would enforce and the more demanding levels that the voluntary instrument would encourage. Therefore, knowledge of the current levels of performance of existing buildings, i.e. performance benchmarks for existing buildings [153] is required to inform these decisions.

Although some argue that generic definition for benchmarking does not yet exist [154,155], in the context of energy use in buildings, it has been widely accepted that benchmarking is a measurement of the effectiveness of energy efficiency improvement measures, indicated by the distances of the observed performance from a benchmark [8,156]. Benchmarking, therefore, involves defining a benchmark, and measuring and comparing performance against the benchmark. It is needed for evaluating the energy performance of a building to confirm compliance with regulatory requirements, and for determining the outcome of a voluntary assessment. A policy mix can be regarded as well-articulated only if the benchmarks used in individual instruments are well co-ordinated.

Most eco-labeling schemes for buildings use the mean or median energy use intensity (EUI) value of a population of similar buildings as the benchmark for comparison with the energy use of the building being assessed. The EUI of a building, in kWh/m^2 per annum, is determined by normalizing the annual energy use in a building by the total floor area of the building. It is by far the most commonly used performance metric for building energy use assessment, although some prefer to use the total number of occupants as the normalizing parameter [157,158]. Other than the mean or median value of a population of buildings, the Energy Star benchmark is set at the top 25th percentile [159]. In using a benchmark that is relative to the general situations, it is important to ensure the database for determining the benchmark will evolve with general improvements in building performance. The currency of the database can be maintained by periodically including the new information obtained in assessing buildings into the database [160].

Since, other than the floor area or occupancy, many factors can affect energy use in buildings, the use of performance metrics like EUI has limitations, as only buildings of similar nature can be compared; and inefficient buildings would be rated as efficient if the entire building population were inefficient. To account for the effects of other influential factors, such as different building and system design features, some building energy codes use regression models that relate EUI to building and system characteristics to determine the benchmarks [161]. Others use a detailed building energy simulation program for the same purpose, which would allow the assessment method to be more generally applicable to building stocks that vary in nature, and to buildings situated in different climatic regions in the same jurisdiction. The building component and system characteristics that are considered to be of minimum acceptable performance are used for determination of the benchmark while the actual energy use of an existing building or the predicted energy use based on the as-designed characteristics of a new building are compared against the benchmark for rating of the building's performance.

However, criticisms have been made that these determination methods are time and effort intensive and unhelpful to the achievement of sustainability. Some considered that only absolute benchmarks that would lead to zero emission at a global scale would be meaningful. This is why absolute benchmarks are used in GBTool [162], and also in the energy standards adopted in California and some other states in the US. However, setting zero emission targets seems unrealistic and is not the only way for achieving environmental sustainability. Sustainability should embrace the interdependent environmental, social and economic dimensions, and should take into account technology advancements and substitution of non-renewable energy resources by renewable resources.

5. Conclusion

Similar to any other government policies, energy policies are institutional arrangements that influence the decision making of individuals and firms, as they attempt to maximize their benefits under the constraints imposed by the policies.

Command-and-control type instruments could incur high institutional costs if used to achieve an ambitious target level far below the current consumption level. Due to the high cost implications to building owners for compliance, opposition to enforcement of regulatory control is likely to occur and, if enforced, could incur high costs for policing and prosecuting violations, rendering the control unenforceable. This explains why only moderate targets can be set, and only a moderate result achieved through the use of this type of instrument. However, it could be highly cost effective if the compliance requirement is set at such a level that the costs for implementing improvement measures can be paid back by the energy cost saving the measures provide, which is possible if there is a significant energy efficiency gap caused by the existence of information barriers.

Other regulatory measures, such as imposing tax over energy use or fines for excessive use, would help reduce energy use and GHG emissions by increasing the costs of energy supply to consumers. This, however, may be considered to be unfair to those who are already performing well but are still subject to the same tax rate. Similar to command-and-control type regulatory instruments, this type of instruments could only lead to moderate results.

Policy instruments may also be used to reduce the costs of implementing energy saving measures to individuals and firms, such as rebates schemes, which will encourage voluntary up take of such measures. However, the costs for measuring the performance improvement achieved can be very high. This type of costs can be largely cut down if the rebate amount is determined with reference to the quantity of energy efficient products adopted or the quantity of inefficient products they replace. Such a scheme, however, would be prone to mistakes and could restrict the choices of building owners in selecting the most cost effective means for enhancing the energy performance of their buildings.

Encouraging the industry to take voluntary actions is also one policy approach that may be used. Greater effect could be achieved if the industry is under the threat that regulatory controls would follow failures in achieving improvement. A better driving force for voluntary actions, however, would still be market force. Eco-labeling schemes have been used to encourage better environmental performance of products, and more recently building assets, using voluntary building environmental performance assessment schemes. If the eco-label can truly reflect enhanced environmental performance of buildings that would be treasured by prospective buyers or tenants of properties, such schemes would encourage building developers to target buildings with higher environmental performance.

As discussed in this paper, all the above approaches have been used in various countries but consensus is still lacking as to which approach is the most effective in reducing GHG emissions, yet minimize any negative impacts on economic development. In choosing a policy instrument, consideration must be given to the effectiveness of each candidate instruments, particularly on the benefits and costs to the building owners and to the society, including the institutional costs incurred.

More ambitious target would need to be achieved through the use of a mix of regulatory and voluntary instruments. The combined use of mandatory building energy codes and voluntary building environmental assessment schemes should be a good approach, as they can share the development costs for the assessment method; can reduce the institutional costs by allowing the regulatory instrument to use a more readily acceptable compliance level; and can reduce the costs of implementation if favorable voluntary assessment outcomes can be regarded as proof of compliance with regulations.

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