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Setting SMART targets for industrial energy use and industrial energy efficiency

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ABSTRACT

Industrial energy policies often require the setting of quantitative targets to reduce energy use and/or greenhouse gas emissions. In this paper a taxonomy has been developed for categorizing SMART industrial energy use or greenhouse gas emission reduction targets. The taxonomy includes volume reduction targets, physical efficiency improvement targets, economic intensity improvement targets and economic targets. This paper also provides a comprehensive overview of targets for industrial energy use or greenhouse gas emission reductions at sector or firm level in past, current and proposed future policies worldwide. This overview includes approximately 50 different emission permit systems, voluntary or negotiated agreement schemes and emission trading systems. Finally, the paper includes an assessment of the various types of targets. The target types are compared with respect to the certainty of the environmental outcome and compliance costs, the targets' relevance for the public and for industry and their environmental integrity, as well as their complexity and potential for comparison.

1. Introduction

Policies directed at improving industrial energy efficiency or limiting emissions related to industrial energy use have existed in many countries since the 1970s. Most often, these policies had a permissive character, i.e. they only intended to stimulate changes in industrial energy use without trying to achieve specific quantitative targets (Keijzers, 2000).

Currently, policies directed at limiting industrial energy use are often embedded in national climate policies. Many countries have set national quantitative greenhouse gas (GHG) emission reduction targets mainly in the framework of the Kyoto Protocol. These quantitative targets for industrial energy use and associated emissions can be set in various ways, at various scales and by different actors. Therefore, target setting for industrial energy use is not connected to a specific policy instrument. Target setting is not only an important element in industrial energy or emission permits but also an important element for voluntary or negotiated agreements. Furthermore, in the case of most emission trading systems, some type of target setting is important in order to set the level from the purchase and sale of emission rights.

It is critical for policy makers to understand the different possibilities for setting quantitative targets for industrial energy use and the process of formulating and setting these targets. This is important for a number of reasons. First, in order to design effective energy and climate policies, policy makers should be able to establish proper targets and review the goal achievement of these targets. Second, in current energy policies it is becoming increasingly important to relate the results of industrial energy policies to the efforts, expressed in financial and administrative terms that are required from the target group. Policy makers should therefore be aware of the economic, social and environmental implications of setting targets on industrial energy use. Third, regulating and motivational properties of different types of targets can be different. A solid understanding of these characteristics is essential when setting new energy targets. Finally, one should have a firm grasp of the extent to which the industrial energy policies contribute to reaching national targets. This is especially important since energy policies are increasingly becoming embedded in national climate policies.

There exists extensive research on the different types of targets that reduce industrial energy use or GHG emissions and an assessment of the associated strengths and weaknesses of said targets. Some papers give insight into the *taxonomy* (Arroyo, 2006) and characteristics of GHG emission reduction targets (WBCSD/WRI, 2004). For example, Arroyo (2006) presents a variety of target types for GHG emission reduction and shows that targets can be set by different actors and at various geographical scales (examples refer mainly to the U.S.). The Greenhouse Gas Protocol (WBCSD/WRI, 2004), a corporate accounting and reporting standard, provides guidance on the

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process of setting corporate GHG targets, amongst others decision making on the target type and other important target characteristics. Many papers *evaluate* volume GHG targets (also known as absolute or fixed targets) in the context of developing alternative climate change commitments at country level such as GHG intensity targets (GHG per unit GDP), command and control measures, carbon taxes and energy technology strategies (see e.g. Philibert and Pershing, 2001; Lisowski, 2002; Aldy et al., 2003). A few papers evaluate volume GHG targets and GHG intensity targets in more detail and compare these targets with respect to e.g. certainty of compliance costs, efficiency of GHG reductions, environmental effectiveness, incentives for technological progress and application for international negotiations on climate change (see Dudek and Golub, 2003; Kolstad, 2005; Pizer, 2005; Herzog et al., 2006). Despite all of this research, none of the papers in recent literature provide a comprehensive *overview* of the current use of different target types in industrial energy efficiency policies or climate policies around the world.[1]

This literature review shows that in previous analyses the use of targets is largely limited to taxonomies, and pros and cons of GHG volume and intensity targets. Other types of targets (e.g. physical efficiency and economic) and energy use targets are typically not taken into account. Furthermore, the different target types are often only discussed as alternatives for national climate commitments. Targets for energy use or GHG emission reduction in the industrial sector and in industrial companies often receive less attention.

These considerations bring us to the research objectives of this paper. The first aim of this paper is to develop a taxonomy of various targets for industrial energy use. We will present an overview of the different approaches for setting targets for industrial energy use and associated GHG emissions. The scope of this paper is limited to so-called SMART targets for industrial energy use and its associated emissions. SMART targets are specific, measurable, appropriate, realistic and timed (see Section 2.3 for further elaborations on the concept of SMART targets). Second, the paper gives a comprehensive overview of the current use of SMART targets limiting industrial energy use and CO_2/GHG emission reduction. We will study the application of the various types of targets in energy and climate policy instruments. The inventory of the different types of targets and their application is based on the experience with target setting in many voluntary agreements and energy regulations in many countries, e.g. see IEA/OECD energy efficiency policy and measures database (IEA, 2008a), the IEA/OECD climate change policy and measure database (IEA, 2008b) and the MURE measure database (FISIR, 2009). Third, the analysis will include an assessment of the various approaches for target setting. A wide range of criteria for assessment of target types was used in related papers (see e.g. Bramley, 2007; Herzog et al., 2006; Kolstad, 2005; Dudek and Golub, 2003; Hoehne, 2006; Edvardsson, 2005; Philibert and Pershing, 2001). We will select and elaborate the criteria that are the most relevant for assessing different types of targets for industrial energy conservation. We will not deal with the various approaches to set the level or the stringency of the targets.

The outline of this paper is as follows. Section 2 describes the purpose of setting policy targets, the rationale behind SMART targets and a further demarcation of the type of targets included in the paper. Section 3 describes different types of industrial targets. Section 4 provides a comprehensive overview of policies for industrial energy use and energy efficiency with SMART targets. Section 5 discusses the different types of targets in more detail. Section 6 evaluates the target types on the basis of several criteria. In Section 7 we will draw the conclusions.

[1] Herzog et al. (2006) do evaluate the use of GHG intensity targets of the most prominent policies around the world, but neglect policies with other types of targets.

2. Targets: definition, functions and SMART conditions

This section defines what a target is and shows how targets relate to policy objectives, strategies and measures (Section 2.1). Furthermore, this section describes the various functions of setting targets (Section 2.2) and the conditions that SMART targets should meet (Section 2.3). We also further demarcate the type of targets included in the paper (Section 2.4).

2.1. The role of targets

In this section we focus on the supporting role of targets in a policy design process. A policy design process ideally consists of the following steps. First, the fundamental principles of policies must be determined. Fundamental principles are the societal key values that underlie the policy. Second, the quality objectives of policies must be specified. A quality objective is defined as ‘a succinct statement of the key goal(s) being pursued over the medium to long-term’ (Marsden and Bonsall, 2006). Third, policy makers should decide upon the concrete policy strategies. Policy strategies are the main patterns of activities to achieve the quality objectives. Finally, policies and measures must be developed (Edvardsson, 2005). Policies and measures are the instruments or tools needed in order to implement the strategies. Targets will specify the level of performance that an entity (organization, firm or (sub)sector) intends to achieve for a particular activity by the implementation of these policies and measures (Marsden and Bonsall, 2006). Quality objectives and policy strategies are often also supported with quantitative targets on a relatively high aggregated level, e.g. national level.[2]

As an example, we will present the role of targets in the Dutch ‘Long-term Agreements on Energy Efficiency’ in the 1990s. The fundamental principles (1) of Dutch energy policy in the 1990s are based on the concept of ‘sustainable development’. The quality objectives (2) of energy policy at that time were reliable, affordable and clean energy supplies. These quality objectives were worked out through several strategies (3), including energy conservation and promotion of renewable energy. A national target was set to improve energy efficiency by 1.7% on an annual basis and to reduce CO_2 emissions by 3% in the period 1989–2000. The strategies included policies and measures (4) stimulating energy conservation. The ‘Long-term Agreements on Energy Efficiency’ were selected as the most important policy instrument for energy conservation. An industry wide target of 20% energy efficiency improvement in the period 1990–2000 and separate sector targets were formulated (EZ/VROM, 1992).

2.2. What are the functions of setting targets?

Setting targets can have various functions in the different phases of the policy cycle. Van Herten and Gunning-Schepers (2000) identify those functions of setting targets for health policy.[3] It is expected that

[2] In this paper we limit ourselves to targets for firms and (sub)sectors (see also Section 2.4).

[3] Marsden and Bonsall (2006) have a slightly different approach by analysing the motivations for the use of targets instead of the functions of using targets. The five principal motivations of using targets are better management, legal and contractual obligations, resources constraints, consumer orientation and political aspirations. WBCSD/WRI (2004) identify similar drivers for companies to adopt GHG targets: minimizing GHG risk, achieving costs savings and stimulating innovation, preparing for future regulation, demonstrate leadership and corporate

those functions are in many cases also valid and similar for energy policy making. We can distinguish the following functions of target setting: to explore, to guide, to motivate and to regulate.

In the policy formulation stage targets can stimulate the debate about GHG emission reductions, give insight into energy use patterns, provide support for priority setting in energy policies, and describe the desired end-state or quality to be reached by energy and climate policies. These processes should be thought of as an exploratory function of setting targets. This exploratory function of setting targets can, for example, be observed in the negotiation phase on the reduction targets in the European burden sharing agreement and the Kyoto Protocol.

In the implementation stage of energy policies targets should stimulate the target group to put efforts in achieving policy targets. A target can either be action guiding or action motivating; Edvardsson and Hansson (2005) make an explicit distinction between the two. A target is action-guiding 'when it directs and co-ordinates action, over time and between agents, towards the desired end-state'. A target is action-motivating when it motivates the target group to take action. In other words, an action-motivating target stimulates a certain type of behaviour of the target group. By doing so, targets improve the commitment of the target group to the policy. Targets can for instance, improve energy management of the target group, by identifying realistic strategies, and specifying timetables and the allocation of resources. This mechanism has for example been observed in the long-term agreement schemes where drawing up energy conservation plans and monitoring of in-company energy use is an important element of learning processes in firms (Blok and Rietbergen, 2004).

In the policy evaluation stage monitoring provides relevant information about the goal achievement for the target group and information for the policy makers about the level of compliance. By doing so, in the final stage of the policy cycle targets have a regulating function by measuring the actual behaviour against the desired behaviour. There are a couple of examples of policy programmes and instruments that have extensive monitoring and reporting procedures, such as the Dutch 'Long-term Agreements on Energy Efficiency Improvement' (Novem, 1999) and the European GHG emission trading scheme (VROM, 2004).

2.3. SMART targets

The concept of SMART goals and targets originates from the idea of 'management by objectives' introduced by Drucker (1954). SMART targets or goals should meet the following conditions: targets must be Specific, Measurable, Appropriate, Realistic and Timed[4] (Van Herten and Gunning-Schepers, 2000; Edvardsson and Hansson, 2005). The level to which these conditions are met determines the ability of the target to guide, motivate or regulate the target group.

The target must clearly specify what is to be achieved. The purpose of specific targets is to guide the target group in a preferred direction. It must be clear to the target group what that direction is and to what degree the goal must be achieved. The more specific the target, the more motivated the target group is to achieve the goal and the better the target group can be regulated. However, the drawback is that very specific targets might neglect some opportunities for reduction of energy use and GHG emissions. Another drawback is that very specific targets might be less relevant for overall policy strategy. Furthermore, the focus is only on achieving the specific target and consequently a genuine motivation for an efficient use of energy might be neglected.

Over the duration of the compliance period the target must allow for regular evaluation of the goal achievement and effectiveness. The purpose of a measurable target is to motivate and regulate the target group, by giving feedback on the goal achievement or checking the compliance.

Targets must be appropriate for the policy maker and the target group. Targets that are relevant for the policy maker are linked to the overall objectives and aims of the authorities' strategy. Thus, targets should contribute to national commitments in international climate change policies. Relevant targets should motivate the target group to be cooperative with overall policy.

The target is achievable within the duration of the compliance period. There are two aspects of target realism: the associated costs and the relative distance. The cost applies to both the size of investment relative to the resources available and/or the profitability of the investment. Relative distance to the target applies to the effort required for the firm or industry to attain the stated goal. Targets should stimulate the companies to go beyond their business as usual trajectory and should therefore be sufficiently ambitious. However, if targets are too ambitious, companies may have little hope of reaching them and therefore, may put in little or no effort (Edvardsson and Hansson, 2005).

Targets must specifically delineate the time period in which the set goals are achieved. Targets should be set for the short to medium term. However, this can lead companies to focus only on meeting the target with little incentive to go beyond it. On the other hand, if targets are not timed, there is little motivation for the target group to put effort in achieving the target. Therefore, targets should be sufficiently ambitious in time.

2.4. Not all targets are SMART

These SMART criteria leave out several types of targets. First, qualitative approaches, such as targets prescribing the use of a certain type of technology, like 'Best Available Techniques', 'As Low As Reasonable Achievable', 'Best Practical Means' or 'Best Technical Means' are not taken into consideration. Those targets are not precise and not easily evaluable since it is not clear to what extent the target has to be achieved and it is difficult to measure the degree of attainment. In practice, the application of these standards often requires further interpretation and additional requirements in quantitative terms, e.g. pay back period. Second, this paper focuses only on specific targets for limiting energy use or the associated CO_2 emissions of industrial processes in the manufacturing industry. The reason for solely focusing on manufacturing industry is that this industry is one of the largest energy-consuming sectors and most energy policies are directed towards this specific sector. By limiting the research to energy use targets for industrial processes, the paper excludes energy efficiency targets and standards for appliances. Third, we also exclude renewable energy targets and targets that are set to limit specific GHGs other than that of CO_2. Fourth, we focus only on targets for individual firms or targets that are set at the sectoral level. National, regional and multi-sectoral targets are not taken into account, since targets at these levels do not specify obligations for individual firms or (sub)sectors and are therefore, not an effective means to stimulate energy efficiency improvement or emissions reduction in firms. Fifth, we exclude aspirational or visionary targets, like for example the target set by the United Kingdom to reduce national CO_2 emission by 60% from 2000 levels by 2050 (DTI, 2003) and the position of the European Union that developed countries should reduce their emissions by 60–80% by 2050 compared to 1990 (CEU, 2007). These kinds of targets are not SMART since they have long-term objectives. To our knowledge aspirational or visionary

(*footnote continued*)
responsibility and participating in voluntary programmes (and thus public recognition).

[4] Sometimes other keywords behind the letters in the acronym are used such as 'significant', 'motivational', 'attainable', 'relevant' and 'trackable'.

targets for policies aimed at industrial energy efficiency improvement do not exist. Finally, result-based targets, like the EU objective to limit average global temperature increase to no more than 2 °C over pre-industrial levels included (EC, 2005) are also excluded. This type of target setting is not appropriate since there is a weak link between the strategy of energy conservation or CO_2 emission reductions and achieving the 2 degree target. Further, the contribution of the manufacturing industry to those targets is not easy to measure and evaluate.

3. Types of SMART industrial energy targets

Targets can be set by different actors in different geographical levels (scope), and under different compliance regimes (see Fig. 1). A variety of actors can set targets for industrial energy efficiency, e.g. by governments unilaterally or bilaterally with industry, by NGOs–industry partnerships, by industrial associations and even by private entities solely.

Furthermore, industrial energy targets can be set at different aggregated levels: e.g. facility level, company level, for a group of companies, (sub)sector level (nationally, regionally or globally). Targets can be further categorized by the degree to which they are truly binding or not (compliance regime). We distinguish mandatory targets, completely voluntary targets and semi-binding targets analogous to Price (2005). Mandatory targets are legally binding targets and non-compliance of these mandatory targets will result in a penalty fee. Voluntary targets are not legally binding and no penalties exist if these targets are not met. Semi-binding targets use the threat of future regulations or energy/GHG emission tax policy as a motivation for compliance. Next, targets can cover energy consumption, CO_2 emissions or (all) GHG emissions. The following categories of quantitative targets can be distinguished: volume targets, physical efficiency targets, economic intensity targets and economic targets. Target categories can be further broken down into target types. A detailed taxonomy of industrial energy use targets is given in Table 1 including some examples. Similar targets can obviously be set for limiting CO_2 and GHG emissions.

There are other distinguishing elements in setting targets that are worth mentioning briefly. First, there are questions related to the product's life cycle. For example, where in the life cycle should the target be applied, and how should system boundaries, like geographical coverage, be drawn to define energy consumption and emissions (see Phylipsen et al., 1998). Second, the length of the commitment period is a distinguishing element. For example, targets may be achieved in one specific year, e.g. limit energy use to 100 PJ in 2020, or within a multi-year period, e.g. limit energy use to 100 PJ in the period 2018–2022. The multi-year commitment period is advantageous because it reduces the risk that unforeseen events negatively influence target achievement. Third, the choice of target base year is also critical. This can either be

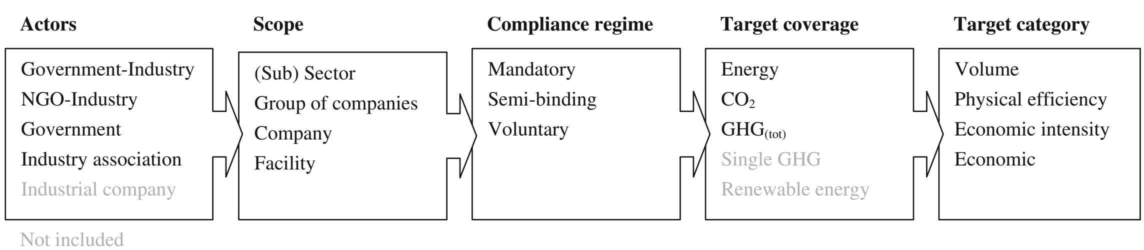

Fig. 1. Different characteristics of targets.

Table 1
A taxonomy of targets for industrial energy use.

Category	Type of target	Example
Volume targets	Energy use target Energy use reduction target	Limit total energy use to 100 PJ by 2020 Reduce total energy use 10% in 2020 compared to the level in 1990 Reduce energy use 5 PJ in 2020 compared to the level in 1990
Physical efficiency targets	Energy efficiency target	The specific energy use should reach a level of 30 GJ/tonne of product in 2020
	Energy efficiency target for new installations	New facilities must operate using the best economic and technical technologies available, being a maximum of 4 GJ/tonne product
	Energy efficiency benchmark target	The company should belong to the 10% most energy efficient in the world
	Energy efficiency improvement target	The specific energy use of a plant should be reduced by 20% by 2020 compared to the level in 1990 (eq. to 20% energy savings in 2020 compared to the frozen efficiency energy use in 1990) Reduce specific energy consumption by 10% by 2020 compared to the BAU (eq. to "10% energy savings by 2020 compared to the BAU) The specific energy use of a plant should be reduced by 1% per year The energy efficiency index of the company must be reduce by 10% in the period 2008–2020
Economic intensity targets	Energy intensity target	The energy intensity should reach a level of 1000 kWh/$ sales by the year 2020
	Energy intensity improvement target	The energy intensity in terms of GJ/$ value added should be reduced with 10% within 5 years
Economic targets	Socio-economic target	All measures with costs less than 20$/GJ energy saved should be taken
	Profitability target	All measures with a pay back period of less than 5 years should be taken
	Ability-to-pay target	All measures should be taken unless the net costs of the measures exceeds 1% of total costs of the company

fixed, e.g. specific energy use of a plant should be reduced 20% in 2020 compared to the level in 1990, or rolling, e.g. specific energy use must be reduced 1% per year (WBCSD/WRI, 2004).[5] It is also possible to use a multi-year average as fixed base value.

4. Policies for industrial energy use and energy efficiency with SMART targets

Targets are used in various types of policy programmes and instruments such as emission trading schemes, environmental permits and voluntary or negotiated agreements. Table 2 provides an overview of the policy programmes and instruments that are included in the analysis.

There are various emission trading schemes worldwide: the national allocation plans in the framework of the European emission trading scheme (EC, 2003) and the linked Norwegian emission trading scheme, the New Zealand emission trading scheme (MFE, 2009) and the 'Carbon Pollution Reduction Scheme' in Australia (DOCC, 2008).[6] All of these emission trading schemes set quantitative mandatory targets. In a few countries voluntary pilot projects on domestic GHG emission trading were set up, e.g. in the United Kingdom (Defra, 2006), Japan (Ninomiya, 2006) and the U.S. (CCX, 2008). In the U.S. the 'Western Climate Initiative' (WCI, 2009), the 'AB32 – the California Global Warming Solutions Act' (CARB, 2009) and the 'American Clean Energy and Security Act' (Larsen et al., 2009), also propose emission trading schemes. One of the compliance mechanisms in the 'Canadian Regulatory Framework for Air Emissions' is also the trading of CO_2 emission allowances (EC, 2007).

There are a few environmental permitting schemes that set SMART targets, such as the environmental permitting system in the Netherlands (VROM, 1999), Belgium (EMIS, 2008) and the United Kingdom (EA, 2002). Permitting schemes in many other countries rely on energy audits and require the implementation of selected energy efficiency measures; those permit schemes are often lacking uniform SMART targets.

Finally there are many voluntary or negotiated agreements that set SMART targets. These agreements can have voluntary, semi-binding or mandatory targets.[7] There is a wide range of agreements with *voluntary targets*. First there are unilateral commitments made by polluters such as the 'WBCSD – Cement Sustainability Initiative' (WBCSD, 2007), the 'Aluminium for Future Generations Initiative' (IAI, 2007) and the 'CEFIC Voluntary Energy Efficiency Programme for the Chemical Industry' (CEFIC, 2005). In these agreements industry unilaterally declares to make quantified commitments to energy reduction use or GHG emission reduction. Second there are agreements (strategic partnerships) between companies and environmental NGOs that set targets on CO_2, GHG or energy use reduction. Examples are the 'Partnerships for Climate Action' by Environmental Defense (Petsonk, 2002), the 'PEW Business Environmental Leadership Council' (PEW, 2007) and the 'WWF Climate Savers Programme' (WWF, 2006). Third, there are agreements between industry and public authorities. Examples of agreements between government and industry with completely voluntary targets are the 'Climate VISION Program' (US-DOE, 2007), 'EPA Climate Leaders' (EPA, 2006a) and 'Environmental Performance Track' (EPA, 2006b) in the U.S., the 'Canadian Industry Program for Energy Conservation' (NRCAN/OEE, 2007), the 'Quebec Voluntary Agreement with Aluminium Industry' (MSDEP, 2006), the voluntary agreements in Korea (Kemco, 2007), the 'Energy Efficiency Agreements' in Finland (Motiva, 2009), the French 'Voluntary Agreements on CO_2 Reduction' (Chidiak, 2002), the 'Self Audit Scheme/Large Industry Energy Network' in Ireland (SEI, 2007), the voluntary agreement on energy between government and aluminium industry in Norway (IEA, 2008b), the voluntary agreement with two steel companies in China (Price et al., 2004), and the negotiated agreement with chemical industries in the United Kingdom (CIA, 1999).

The voluntary or negotiated agreements with *semi-binding targets* are the French 'AERES Negotiated Agreements' (AERES, 2008), the 'Joint Declaration on Global Warming Prevention' in Germany (Ramesohl and Kristof, 2000) followed by the 'Agreement on Climate Protection' (RWI, 2005), the first generation of 'Long-term Agreements on Energy Efficiency' in the Netherlands (EZ, 1998), followed by the second and third generation of long-term agreements and the 'Benchmarking Covenant on Energy Efficiency' (EZ, 1999), the 'Audit Covenant' and the 'Benchmarking Covenant on Energy Efficiency' in Flanders – Belgium (VAV, 2007; CB, 2007), the voluntary agreements on energy efficiency in Wallonia – Belgium (MRW, 2002), the 'Keidanren Voluntary Action Plan on the Environment' in Japan (Keidanren, 2006) and the voluntary agreements to limit CO_2 emissions in New Zealand (Jamieson, 1996).

The government–industry agreements with *mandatory targets* are the negotiated greenhouse agreements in New Zealand (MFE, 2005), the Danish 'Agreements on Industrial Energy Efficiency' (Krarup and Ramesohl, 2000), the Canadian 'Regulatory Framework for Air Emissions' (EC, 2007), voluntary measures under the CO_2 law in Switzerland (IEA, 2008b), the United Kingdom 'Climate Change Agreements' (Ekins and Etheridge, 2006), the 'Programme for Energy Efficiency' in energy intensive industry in Sweden (SEA, 2007) and the 'Top 1000 Industrial Energy Efficiency Programme' in China (Price et al., to be published).

5. Unfolding SMART energy and CO_2/GHG targets

5.1. Volume targets

Although volume targets have been fairly common in areas of environmental policy, in the area of energy use and GHG emissions they have been scarce until the 21st century. Volume targets prescribe that a company or a sector is not allowed to use more than a certain amount of energy or emit more than a certain amount of CO_2/GHG emissions at a fixed point in the future (energy use or CO_2 emission target in absolute terms). Alternatively, volume targets can also require that a certain percentage of the energy use or CO_2/GHG emissions must be reduced relative to a base year at some fixed point in the future (energy or CO_2 emission reduction targets in relative terms). In both cases volume targets must ultimately limit or reduce energy use or CO_2/GHG emissions to a certain absolute level.

5.1.1. Energy use targets

Energy use targets are predominantly used in bilateral government–industry agreement schemes or partnerships and NGO–industry partnerships, but are less common than other types of targets (see Table 2). Energy use targets are more commonly expressed in relative terms, e.g. "the total energy use

[5] See WBCSD/WRI (2004) for a comparison of targets with rolling and fixed base years.

[6] Schemes especially designed for emission trading among electricity producers and large electricity consumers are not included.

[7] We have tried to include all target-based agreements with negotiated targets at company or sub-sector level and performance based agreements with quantitative performance goals at company or sub-sector level (see Storey et al., 1997). Excluded are performance-based agreements with quantitative targets at multi-sector industrial level and performance-based agreements requiring an energy auditing procedure without clear target setting for the implementation of energy efficiency measures.

Table 2
Policy programmes with SMART targets.

Country	Policy programme	Start	Stop	Compliance regime	$E/CO_2/GHG$ cap	$E/CO_2/GHG$ emission reduction	SEC/SCE (absolute)	SEC/SCE improvement (relative)	EEI/ CO_2EI	$E/CO_2/GHG$ efficiency benchmarking	Minimum energy/ CO_2 efficiency	Energy/ CO_2/ GHG intensity (absolute)	Energy/ CO_2/GHG intensity improvement (relative)	Economic	References
Environmental permit															
Belgium	Environmental permit	2004	–	R										PBP	EMIS (2008)
Netherlands	Environmental permit	1994	–	R										PBP	VROM (1999)
UK	Environmental permit	2002	–	R										Cspec	EA (2002)
Emission trading															
Australia	Carbon pollution reduction scheme	2010	–	R										Cspec	DOCC (2008)
EU+EEA	European emission trading scheme	2005	2008	R	C										EC (2003)
Japan	Voluntary emission trading scheme	2005	2007	V		C									Ninomiya (2006)
New Zealand	Emission trading scheme	2010	–	R	C										MFE (2009)
United Kingdom	UK emissions trading scheme (pilot)	2002	2006	V		C									Defra (2006)
USA	Chicago climate exchange	2003	2010	R		C									CCX (2008)
USA	American clean energy and security act (proposed)	2012	2050	R	C										Larsen et al. (2009)
USA	AB32 – California global warming solutions act (proposed)	2012	2020	R	C										CARB (2009)
USA	Western climate initiative (proposed)	2012	–	R	C										WCI (2009)
Voluntary agreements – unilateral industry agreement															
EU	Voluntary energy efficiency programme chemical industries (CEFIC)	1992	2005	V				E							Cefic (2005)
Global	Cement sustainability initiative (WBCSD)	2002	–	V			C	C							WBCSD (2007)
Global	Aluminum for future generations (IAI)	2003	–	V				E							IAI (2007)

Voluntary agreements – between industry and public authority															
Belgium	Benchmarking covenant (Flanders)	2004	2012	Th						E				IRR	CB (2007)
Belgium	Voluntary agreements (Wallonia)	2000	2012	Th					C/E					PBP	CGW (2007)
Belgium	Audit covenant	2005	2013	Th										IRR	VAV (2007)
Canada	Regulatory framework for air emissions	2006	2010	R				C						Cspec	EC (2007)
Canada	Industry program for energy conservation	1975	–	V				E					E		NRCAN/ OEE (2007)
Canada	Quebec voluntary agreement with aluminum industry	2002	2012	V	C						C				MSDEP (2006)
China	Top 1000 industrial energy efficiency programme	2005	2010	V			E	E							Price et al., to be published
China	Shandong pilot project voluntary agreement with 2 steel companies	2003	2005	V				E							Price et al. (2004)
Denmark	Agreements on industrial energy efficiency	1993	–	R										PBP	Krarup and Ramesohl (2000)
Finland	Energy efficiency agreements	2008	2016	V				E				E			Motiva (2009)
France	Voluntary agreements on CO_2 reductions	1996	2002	V		C	C								Chidiak (2002)
France	AERES negotiated agreements	2002	2007	Th	C		C								AERES (2003)
Germany	Joint declaration on global warming prevention	1995	2000	Th		C/E	E	C/E					C		Ramesohl and Kristof (2000)
Germany	Agreement on climate protection	2000	2012	Th		C		C/E					C		RWI (2005)
Ireland	The self audit scheme/large industry energy network	1994	–	V				E	E						SEI (2007)
Japan	Keidanren voluntary action plan on the environment	1997	2010	Th	C/E	C/E		C/E							Keidanren (2006)
Korea	VA system for energy conservation & reduction of GHG emissions	1998	–	V		C		C/E					C/E		Kemco (2007)
Netherlands	Long term agreements 1	1992	2000	Th					E				E		EZ (1998)
Netherlands	Long term agreements 2	2000	2012	Th					E					PBP	EZ (2003)

Table 2 (*continued*)

Country	Policy programme	Start	Stop	Compliance regime	E/CO_2/GHG cap	E/CO_2/GHG emission reduction	SEC/SCE (absolute)	SEC/SCE improvement (relative)	EEI/CO_2EI	E/CO_2/GHG efficiency benchmarking	Minimum energy/CO_2 efficiency	Energy/CO_2/GHG intensity (absolute)	Energy/CO_2/GHG intensity improvement (relative)	Economic	References
Netherlands	Long term agreements 3	2008	2020	Th					E					PBP	EZ (2008)
Netherlands	Benchmarking covenant	2001	2012	Th						E					EZ (1999)
New Zealand	VAs to limit carbon dioxide emissions	1995	2000	Th				C							Jamieson (1996)
New Zealand	Negotiated greenhouse agreements	2003	2005	R						C					MFE (2005)
Norway	Voluntary agreement with aluminum industry	1997	2005	V				C							IEA (2008b)
Sweden	Programme for energy efficiency in energy intensive industry	2005	2010	R										PBP	SEA (2007)
Switzerland	CO_2 target agreements – voluntary agreement	2001	–	Th					E						SAEFL (20010
Switzerland	CO_2 target agreements – formal commitment	2001	–	R	C				C						SAEFL (2001)
United Kingdom	Negotiated agreement with chemical industry	1990	2005	V				E							CIA (1999)
United Kingdom	Climate change agreements	2001	2013	R		C/E	E	C/E	C/E			E			ETSU (2001)
USA	Climate VISION	2003	–	V		C/E		C/E							US-DOE (2007)
USA	Environmental performance track	2000	2009	V	C/E										EPA (2006b)
USA	EPA climate leaders	2002	–	V		C		C					C		EPA (2006a)
Voluntary agreements – between polluters and pollutes															
Global	Climate savers (WWF)	1999	–	V		C		C							WWF (2006)
Global	Partnerships for climate action (environmental defense)	2000	–	V	C	C									Petsonk (2002)
Global	Business environmental leadership council (PEW)	1998	–	V	C	C/E		C/E				C			PEW (2007)

V = voluntary target, R = binding target, Th = non-compliance threatened by regulatory measures, C = CO_2/GHG target, E = energy target, PBP = pay back period, IRR = internal rate of return, Cspec = specific CO_2 mitigation costs.

must be reduced with 10% in 2020 compared to the level in 1990", than in absolute terms, e.g. "the total energy used must be limited to 100 PJ in 2020".

An early European example of an agreement scheme with an energy use reduction target in relative terms is the declaration of the German textile industry on energy saving and CO_2 emission reduction. The textile industry committed itself to reduce energy use by 20% in the period 1987–2005. A more recent example that also has the least permissive character is the sector target set by the British steel industry in the framework of the 'Climate Change Agreements' in the United Kingdom. The steel industry is one of the few sectors that had agreed upon an energy use reduction target. The target is to reduce energy use by 11.5% in 2010 compared to the level in 1997 (ETSU, 2001). In the Japanese 'Keidanren Voluntary Action Plan on the Environment' (Keidanren, 2006) launched in 1997, a minority of the industrial sectors have defined energy use reduction targets. For example, the Japanese iron and steel industries have set a target to reduce energy consumption in 2010 by 10% compared with energy consumption in 1990.

5.1.2. CO_2/GHG emission volume targets

Currently, volume targets for CO_2 or GHG emissions are emerging rapidly. These types of targets are used in various types of policy programmes, such as emission trading schemes and voluntary agreement schemes. Both CO_2/GHG emission caps, e.g. limit total CO_2/GHG emissions to 1000 ktonne CO_2eq in 2020, and CO_2/GHG emission reduction targets, e.g. reduce total CO_2 emissions 10% in 2020 compared with the level in 1990, are frequently used.

The Kyoto Protocol and the distribution of national climate commitments is obviously the most important example of global energy and climate policies that set CO_2/GHG emission volume targets. The European Community is committed to achieving an 8% reduction of GHG emissions by the year 2008–2012 compared to 1990 levels. The member states of the European Union have agreed to fulfil their commitments jointly. In 2005 a scheme for the trading of greenhouse gas emission allowances in the European Union came into effect. Each member state had to draw up a national allocation plan stating the total quantity of allowances that it intended to allocate and how the allowances would be distributed among the participants in the ETS. There are three distinctive methods to allocating CO_2 emission allowances: *grandfathering*, *benchmarking* and *auctioning*.

Grandfathering provides emission allowances free of charge to the participants. The allocation is based on historic emissions of the participant and can be modified by including other factors such as sector-specific growth rates, capacity utilization rates and energy efficiency benchmarks. Grandfathering has been the main approach used to allocate emission allowances in the first and second phase of the EU ETS.

Like grandfathering, *benchmarking* also provides emission allowances for free, but benchmarking allocates emissions on the basis of a GHG or energy efficiency benchmark, e.g. tonne CO_2/tonne of product, and the production level (Groenenberg and Blok, 2002). Up till now, benchmarking has only been used as a method to allocate emissions for new entrants in energy-intensive industries.

In some EU member states, a small share of the emission allowances has been auctioned. In the case of *auctioning*, emission allowances are sold to the highest bidder. Setting targets at firm level is therefore unnecessary. Full auctioning will be used in the 'Carbon Pollution Reduction Scheme' in Australia (DOCC, 2008). This scheme only sets limits to the all emission sources covered and not to individual firms or facilities.

Next to emission trading schemes, there are also a wide range of voluntary or negotiated agreements with CO_2/GHG emission volume targets. The Swiss CO_2 target agreement is an example of a voluntary agreement between industry and public authority with CO_2/GHG emission targets expressed in absolute terms. In this agreement, firms adopt binding CO_2 caps, which exempt them from a CO_2 tax. A second example is the EPA 'Climate Leaders Program' in the U.S. Several companies committed themselves to CO_2 or GHG emission volume reduction targets expressed in a relative terms, e.g. Eastman Kodak itself committed to a 10% reduction of GHGs in 2008 compared to the level in 2004. The potash industry is the only sector under the German voluntary agreements that adopted CO_2 emission volume reduction targets (78% CO_2 emission volume reduction in 1990–2005).

CO_2/GHG emission volume targets are also commonly used in bilateral NGO–industry partnerships, such as the 'WWF Climate Savers Programme'. By 2006, 11 international partners had set a corporate-wide GHG volume reduction goal and created inventories of their emissions in order to measure progress (WWF, 2006). One company, Johnson and Johnson, set a 7% GHG emission reduction target by 2010 compared to the 1990 level.

5.2. Physical efficiency targets

Physical efficiency targets are quite common in energy and climate policies. These targets can either aim at a certain energy efficiency or CO_2 efficiency level at a fixed point in the future (physical efficiency targets in absolute terms) or aim at a certain improvement of energy or CO_2 efficiency compared to a business as usual case or a base year (physical efficiency improvement targets in relative terms).

5.2.1. Energy efficiency targets: specific energy consumption and EEI

Energy efficiency is defined as output per unit energy input. For industrial processes in general, the inverse of energy efficiency, i.e. the specific energy consumption (or specific energy use, unit energy use or physical energy intensity) is used:

$$SEC = \frac{E}{P} \tag{1}$$

where *SEC* is the specific energy consumption, *E* the energy input to the process and *P* the output of production process.

Energy efficiency targets are used in multiple types of voluntary agreements schemes (see Table 2). Energy efficiency improvement targets, like "the SEC of a plant should be reduced by 20% in 10 years" (relative reduction of SEC) are very frequently used, whereas energy efficiency targets, like "the SEC should reach a level of 30 GJ/tonne ammonia" (absolute target value for SEC) are not.

The few examples of agreements with efficiency targets expressed in terms of an absolute target value for the SEC can be found in the British 'Climate Change Agreements', where e.g. the brewing industry has set a goal to achieve a primary SEC of 56.94 kWh/hectolitre by 2010, and in the German 'Declaration on Global Warming Prevention', where the sugar industry is aiming at the limitation of energy use per tonne of sugar beet to 29 kWh/tonne in the period 1990–2005. Energy efficiency benchmarking agreements are another example of policy instruments using efficiency targets expressed in terms of an absolute target value for the SEC. In fact, benchmarking is an approach to setting the level of a target. A benchmark target is an energy efficiency target that is dependent on the performance of the other firms in a more or less homogeneous group. A benchmark procedure typically works as follows: the SEC is determined for a group of homogeneous firms, e.g. all ammonia producers in the world. Subsequently, the firms are ordered according to increasing SEC and a benchmark target for a specific company could then require the company to implement improvements so that it shifts into a lower percentile of the population. Such a benchmarking target is used in the Dutch 'Benchmarking Covenant on Energy Efficiency', concluded in 1999 between the Dutch government and energy-intensive industries (energy consumption >0.5 PJ per unit per year). According to the covenant, energy-intensive industries are obliged to be among the leaders in energy efficiency for processing installations by 2012. The Belgium government subsequently concluded a similar benchmarking covenant with energy intensive industries.

Many sector agreements in the German 'Declaration on Global Warming Prevention', the German 'Agreement on Climate Protection', the Japanese 'Keidanren Programme' and the British 'Climate Change Agreements' have set energy efficiency improvement targets expressed in terms of a relative reduction of the SEC: e.g. the German cement industry aimed at a 20% reduction in the specific fuel consumption kJ fuel/kg cement produced (1987–2005) and the British textile industry aimed at a 9% reduction of primary SEC from 1999 to 2010.

China introduced the 'Top-1000 Energy-consuming Enterprise Programme'. Firms participating in this programme must adopt 'energy-saving' targets. The energy saving target is an absolute energy saving value that each enterprise is expected to save in 2010 against a growth baseline (Price et al., to be published). The target achievement depends on the production volume and the reduction of SEC.[8]

For individual processes or sectors that are dominated by one individual process, the SEC is a useful measure of energy efficiency. However, most industries and sectors produce a mix of products. In that case the SEC should be replaced by an energy efficiency index (EEI). The EEI is a weighted average of the values of the SEC for a range of products[9]:

$$EEI = \frac{\sum_{x=1}^{n} SEC_x P_x}{\sum_{x=1}^{n} SEC_{ref,x} P_x} = \frac{E_{actual}}{E_{frozen\ efficiency}} \tag{2}$$

where EEI is the energy efficiency index of an industrial sector, E the actual total energy use of an industrial sector in a specific year, P_x the production volume for product x in a specific year, SEC_x the specific energy use for product x in a specific year and $SEC_{ref,x}$ the reference specific energy use for product x.

The problems associated with constructing an EEI are discussed in Phylipsen et al. (1998). One of the crucial aspects is the choice of a set of reference values for the specific energy consumption ($SEC_{ref,x}$). Various options are available, e.g. historic levels of the SEC of the various products, best practice levels or best-plant levels of the various product SECs.

A target for the reduction of the EEI was used in the first generation of 'Long-term Agreements on Energy Efficiency' for the Netherlands. The target was to decrease the EEI over the period 1989–2000 with a certain percentage, generally about 20%. This can be indicated as an energy efficiency improvement target in relative terms: the weighted energy consumption per unit product should be decreased by 20%. The EEI is also used as a target in the voluntary agreements between industry and the Wallonia government in Belgium, the 'Climate Change Agreement' with chemical industry in the United Kingdom and the voluntary CO_2 target agreement in Switzerland.

5.2.2. CO_2/GHG efficiency targets: specific CO_2/GHG emissions and CO_2EI

CO_2/GHG efficiency targets can be set analogous to Eqs. (1) and (2). Such targets are used in various types of policy instruments (see Table 2). CO_2/GHG efficiency improvement targets, like "the specific CO_2 emissions (SCE) of a plant should be reduced by 20% in 10 years" (relative reduction of SCE) are very frequently used, whereas CO_2/GHG efficiency targets, like "the SCE should reach a level of 1000 kg/tonne of product" (absolute target value for SCE) are not.

The 'AERES Negotiated Agreements' with French industry are the only known examples of policy instruments with CO_2/GHG efficiency targets expressed in terms of an absolute target value for SCE. Under these agreements, for example, the French glass industry agreed that firm-level SCE must reduce emissions to 692 kg CO_2 per tonne of glass produced in 2007. Approximately half of the 33 agreements under the AERES programme set this type of target.

Efficiency targets in absolute terms are often used to limit energy use and emissions in buildings, appliances and equipment. Absolute target values for the SCE applied as a minimum CO_2 efficiency level for new process installations are however scarce. One distinctive example of such targets was found in a sector agreement between the government of the Canadian Quebec region and the aluminium industry. In this agreement they utilise the concept of 'Best Available Technology Economically Achievable'. As part of the agreement, the sector 'ensures' that new facilities will operate using the best economic and technical technologies available, being a maximum of 2 tonne of CO_2eq per tonne of aluminium produced (MSDEP, 2006).

CO_2/GHG efficiency improvement targets expressed in terms of relative reduction of the SCE can be found in many sector agreements in the German 'Declaration on Global Warming Prevention'. The overall target of the German 'Declaration on Global Warming Prevention' is to reduce the SCE by 20% in 2005 from the level of 1990. The target of the follow-up agreement ('German Agreement on Climate Protection') is a reduction of SCE by 28% in the period 1990–2005 and reduce its specific emissions by 35% in 2012 compared to the 1990 level. The target for 2012 includes CO_2 as well as the five other GHGs controlled under the Kyoto Protocol. The industrial sectors contribute to the overall target with different sector targets. Many industrial sectors, such as the potash,[10] ceramic and paper industries have set sector targets in terms of relative reduction of SCE per tonne of product. In Canada the 'Regulatory Framework for Industrial Air Emissions' requires that each sector reduces the SCE from combustion and non-fixed process emissions by 6% annually in the period 2007–2010 and thereafter by 2% annually (EC, 2007). The target must primarily be achieved through emission abatement actions.[11]

[8] Energy savings in year i compared to the previous year $i-1$ are calculated with the following formula (Price et al., to be published):

$$E_{savings,i} = P_i(SEC_{i-1} - SEC_i)$$

[9] If specific energy use of products is unknown project monitoring can be used to calculate the EEI. EEI is then calculated by

$$EEI = \frac{E}{E + \Delta E_{realisedsavings}}$$

This methodology is for example applied in the Swiss voluntary CO_2 target agreements and in some sectors/companies participating in the first generation of the long-term agreements in the Netherlands.

[10] The potash industries have also formulated a CO_2 volume reduction target.

[11] There are also limited possibilities to comply with these targets through other mechanisms: (1) firms could meet their compliance obligations through contributions to a technology fund (see Section 5.5.2; (2) emissions trading; (3) credits from the Kyoto Protocol's Clean Development Mechanism and (4) recognition of early action.

There exist two examples of agreements that include a CO_2 efficiency index (CO_2EI), analogous to Eq. (2). The CO_2EI is used in the Wallonia voluntary agreements on energy (MRW, 2002) and in the 'Climate Change Agreement' with aluminium industries in the United Kingdom.

5.3. Economic intensity targets

Economic intensity targets aim at decoupling the energy use or emissions from economic output. These targets can set limits to the ratio of energy use (or CO_2/GHG emissions) and the economic activity (economic energy or CO_2/GHG intensity target in absolute terms) or aim to improve this ratio (economic energy or CO_2/GHG intensity improvement target in relative terms). The economic activity can be expressed in terms of the value of production, value added, revenue or sales:

$$\varepsilon = \frac{E}{A} \tag{3}$$

where ε is the economic energy intensity, E the energy input to the process and A the economic activity

Economic intensity targets are sometimes proposed as alternative approaches for binding Kyoto commitments at the national level. The U.S. and Argentina for example, use national level economic intensity targets; however, economic energy or CO_2 intensity targets are rarely used in industries. The companies or sectors that do set energy intensity targets are generally not the most energy intensive industries.

There are some examples of companies or sectors that have set their own economic energy or CO_2/GHG intensity improvement targets in relative terms. In the 'EPA Climate Leaders Program' the pharmaceutical company Pfizer intends to reduce global GHG emissions by 35% per dollar of revenue between 2000 and 2007 (EPA, 2006a). Electrotechnical industries in Germany have set economic energy intensity improvement targets in the 'Joint Declaration on Global Warming Prevention' as well as in the following 'Agreement on Climate Protection'. The target set in the Agreement on Climate Protection' is a 40% reduction in the CO_2 emission per € production value in the period 1990–2012 (RWI, 2005). In the first generation of the 'Long-term Agreements on Energy Efficiency' in the Netherlands, Philips Electronics set a 25% target to improve economic energy intensity, defined as energy use divided by the total value of production, in the period 1989–2000.

In the framework of the 'Climate Change Agreements' in the United Kingdom, the sector craft bakeries and supermarkets are the only sectors that have set an absolute target value for the economic energy intensity; the target is to achieve a 1160 kWh/£k added value in 2010 (ETSU, 2001).

5.4. Hybrid targets

The energy efficiency targets of the German chemical industries, in the framework of the 'Agreement on Climate Protection' and the 'Joint Declaration on Global Warming Prevention', are measured by dividing the energy index in the sector by a production index as given by

$$SEC = \frac{\textit{energy index}}{\textit{production index}} = \frac{(E/E_0)}{\sum_{k=1}^{n} b_k I_k} \tag{4}$$

and

$$I_k = \sum_{x=1}^{n} g_j V_j$$

where SEC is the specific energy consumption of an industrial sector, I_k the production index of the sub sector k, b_k the share of the sub sector in the value added of the total sector at factor costs in the base year, E the total energy consumption of sector in a specific year, E_0 the total energy consumption of sector in the base year, g_j the share of production value in the gross production value in the sub sector in the base year and V_j the production volume index.

The production volume can be based on physical output in case very homogenous products are produced such as in the sector of basic chemicals or on the basis of the production value, corrected for inflation, in sub sectors with heterogeneous products or products with significant quality differences. Apart from the sub sector of basic chemicals all other sub sectors in the chemical industries report production volume on the basis of the production value. The advantage of using the ratio of the energy index and production index above the EEI is that reference values of the SEC of the various products are not needed, while it still takes into account structural changes in the sector. This type of target makes it possible to construct a hybrid production index, where physical production values and economic values of production are combined.

5.5. Economic targets

Economic targets have not been used very frequently in energy policies. However, the level of many other types of targets, such as volume and physical efficiency targets are based on a techno-economic assessment. Economic targets take into account costs and or revenues of energy saving investments, which help to define the financial burden for individual firms. We distinguish socio-economic targets, profitability targets and ability-to-pay targets.

5.5.1. Profitability targets

Profitability targets require that all energy saving measures implemented be economically attractive from a private perspective. A specific cut-off maximum pay back period (PBP), e.g. 5 years or a positive net present value (NPV) at a certain discount rate (e.g. 15%) can be used to assess the profitability of energy saving measures.

Since the beginning of this decade, profitability targets have been used more frequently in energy policy instruments. However, these types of targets are only used in unilateral government decisions and bilateral industry–government agreements. The Danish 'Agreement Scheme on Industrial Energy Efficiency' (Krarup and Rahmesohl, 2000) is one of the earliest examples of policy instruments to set profitability targets. They require companies to implement all energy conservation projects with a PBP of less than 4 years. As part of the agreement, that can either be individual or collective, companies receive a CO_2-tax rebate. The Swedish 'Programme for Energy Efficiency' in energy-intensive industries, introduced in 2005, has a similar scheme. Participating companies must implement an energy management system and carry out an energy audit in the first 2 years. During the remaining 3 years the companies must implement energy efficiency measures that have a PBP less than 3 years (SEA, 2007).

Profitability targets are also used in the Dutch environmental permit system and the second and third generation of 'Long-term Agreements on Energy Efficiency' in the Netherlands. Firms are required to implement all energy saving measures *that could reasonably be asked*. Under this scheme, the measures 'that could reasonably be asked' is defined as measures with a positive NPV at a discount rate of 15% (VROM, 1999; EZ, 2003; EZ, 2008). This corresponds to a PBP of approximately 5 years. Similar energy requirements can be found in the environmental permitting

Table 3
Assessment summary of the target options.

Assessment criteria	Low		High
Certainty of environmental outcome	Physical efficiency target Economic intensity target Economic target		Volume target
Environmental integrity	Economic intensity target Volume target		Physical efficiency target Economic target
Certainty of compliance costs	Volume target	Physical efficiency target Economic intensity target	Economic target
Public relevance	Economic target	Physical efficiency target Economic intensity target	Volume target
Relevance for industry	Volume target	Economic intensity target	Physical efficiency target Economic target
Potential for comparison	Volume target	Economic intensity target Economic target	Physical efficiency target
Complexity	Volume target	Physical efficiency target	Economic intensity target Economic target

system and in the 'Audit Covenant' in Belgium. According to this 'Audit Covenant', medium-sized energy intensive firms (0.1–0.5 PJ/year) must carry out energy audits and all the measures with an IRR of 15% or more must be implemented in the first phase. In the second phase less attractive measures with an IRR of 13.5% or more must be taken (VAV, 2007).

5.5.2. *Socio-economic targets*

Socio-economic targets require that all measures meeting a certain cost-effectiveness criteria must be implemented. The cost-effectiveness of energy efficiency measures from a social perspective can be expressed in terms of specific costs. These are the costs per unit of effect obtained. Examples are the specific cost of saved energy ($/GJ) and the specific CO_2 mitigation costs ($/t$CO_2$).

A number of policy instruments that set requirements to specific costs as a target for industrial conservation propose this type of target setting. The 'Regulatory Framework on Air Emission' in Canada sets binding targets for specific CO_2 emission reductions. To a limited extent these regulatory obligations can be met by contributing to a so-called climate change technology fund at a rate of 15CAN$ (around 10€) per tonne of carbon dioxide equivalent from 2010 to 2012 and 20CAN$ (around 13€) per tonne in 2013. Thereafter, the rate is pegged to the growth rate of nominal GDP. The fund will be used to invest in new technologies that are shown to yield CO_2 emission reductions (EC, 2007). These limits to specific costs are also known as price caps and the safety valve. In the Australian 'Carbon Pollution Reduction Scheme' emission allowances are auctioned but the government has decided to set a price cap for 5 years of 40AUS$ (around 25€) per tonne CO_2, rising at 5% per annum (DOCC, 2008). A third example of a socio-economic target is the energy efficiency requirements in the IPPC guidelines in the United Kingdom. Operators that do not participate in the climate change agreements or operators that fail to meet these obligations, must draw an energy efficiency plan and rank all energy efficiency measures on the basis of specific costs. Each measure that results in net costs savings should be considered for implementation (EA, 2002). The discount rate should be selected by the operator, but typically varies between 6% and 12% in the United Kingdom. According to EA (2002), the Environment Agency is also considering requiring the implementation of techniques that have positive specific costs. To date, no progress has been made on developing stricter targets.

5.5.3. *Ability-to-pay target*

A type of target that is not being used in practise is the ability-to-pay target. Similar to the profitability target, the ability-to-pay target also takes into account the reasonability of the energy saving investments from a private perspective. The implementation of energy saving measures should not substantially affect the competitiveness of the firms. The ability-to-pay target does take into account the total investment costs of energy saving; whereas the profitability target and the social-economic target do not do that. There are different possibilities to design such ability-to-pay targets, e.g. firms should take all energy saving investment unless the net costs of the measures exceeds *x*% of the total production costs, *x*% of the total turnover or *x*% of the total profits. Blok and Rietbergen (2004) have analysed the impact of a standard that requires firms to take all energy saving investment unless the net costs of these measures exceed 0.2% of the total costs of the company. It appears that such an ability-to-pay target leads to similar energy savings as in a regime that uses profitability criteria of no more than 5 years.

6. Assessment of the different target options

One objective of this paper is to assess various approaches used in setting targets. A wide range of criteria for assessment of target types has been used in related papers. For example, Bramley (2007) uses the criteria of environmental fairness, economic feasibility (profitability, ability-to-pay, cost-effectiveness), environmental integrity, cost (un)certainty, urgent action and geographical balance. Herzog et al. (2006) evaluate environmental effectiveness, complexity and public understanding, data verification and compliance, and interaction with emission trading. Additional criteria found in other papers are e.g. potential for (international) comparison, encouragement of early action (Hoehne, 2006), relevance for the target group (Edvardsson, 2005), contribution to economic growth (Philibert and Pershing, 2001), incentives for technological progress and relevance for international climate policies (Dudek and Golub, 2003).

In this paper we assess the target types on the basis of the following criteria. First, we discuss the (un)certainty of environmental outcome. Some target types will not lead to a particular environmental outcome while others do. Second, we look at the environmental integrity of targets; a target type must guarantee that the environmental outcome and achievement of the targets is the result of real abatement (no loopholes). Third, an issue that is often debated is the (un)certainty of compliance costs. Some target types do not give sufficient insight in the total costs involved to compliance with the target level. Fourth, we evaluate the public relevance. We question whether the target is linked to current climate change policies or not. Fifth, we discuss the relevance of the target for the industry. Targets that are relevant for industry are most likely to be better accepted and subsequently, more easily adopted. Some target types align better with certain business strategies or decision-making processes than other types of targets. Sixth, we discuss whether the targets allow for a good international or national comparison. Finally, we will look at the complexity of the target (Table 3)

6.1. (Un)certainty of the environmental outcome

Volume targets may look very appealing to governments since the impact on the environment in terms of energy use reduction or CO_2/GHG emission reduction is clearly stated in the case of full compliance. In contrast, physical efficiency targets do not control the total energy use and its related emissions of a firm or a sector; these targets allow industries to grow their energy use and emissions. In order to limit uncertainties in the environmental outcome of these targets good insight into the business-as-usual scenario is required. Alternatively, a feedback loop can be used to regularly adjust the efficiency targets in order to achieve the preferred environmental outcome. However, this will lead to 'uncertainty of effort' among the regulated firms (ESST, 2008).

In the special case of a benchmarking target, companies do not have to perform better than the peer group. Consequently, these targets do not lead to the best environmental outcome possible. Another problem with benchmarking is that setting the level of the target may be difficult: it is difficult to assess the energy efficiency of the world top because of the strategic value of this type of information.[12] Similar to physical efficiency targets, the environmental outcome of economic intensity targets is uncertain. Economic intensity targets permit the unlimited growth of energy use or emissions as long as it is compensated by a growth in the economic output of a sector or firm (Lisowski, 2002). The stringency of the target can be hard to evaluate depending on the indicator measuring the economic activity. Economic targets also do not control the absolute emissions. The stringency of the target determines whether the environmental outcome goes beyond the business-as-usual effects.

6.2. Environmental integrity

Although the environmental outcome of policies and measures with volume targets is certain in the case of full compliance, it does not mean that the quality of the outcome is satisfactory (Herzog et al., 2006). The total energy use and emissions can also be reduced, e.g. (1) if industrial facilities change owners, (2) by outsourcing industrial activities or (3) closing down plants, reducing domestic activities and increasing it overseas and (4) structural changes in the production (Elliot, 2003). In those cases, energy use and GHG emissions are not reduced by the implementation of GHG abatement technologies. A regular adjustment of volume targets may be necessary in order to assure the environmental integrity of the target achievement. The environmental integrity of physical efficiency targets is much more certain, since the commitment level for companies remains the same if output fluctuates. Furthermore, there is a direct relationship between the target and energy efficiency technology since the effect of energy saving measures is expressed in terms of physical efficiency improvement (Phylipsen et al., 1998). Moreover, physical energy efficiency targets can take into account both the increase in the production volume and in particular cases, structural changes in the product mix. The environmental integrity of economic targets is also assured while these target types are met by implementing energy efficiency measures on a project basis. Meeting the economic intensity target does not necessarily mean that it has been achieved by the implementation of abatement technologies: economic intensity targets can be achieved by increasing the economic output, reducing energy use/GHG emissions or a combination of both.

6.3. (Un)certainty of compliance costs

One of the major disadvantages of volume targets is the high uncertainty of the costs related to achieving the target. The (un)certainty of the costs for complying with the volume targets depends on the (un)certainty in the output level at the end of the commitment period and the uncertainty in the emission abatement costs at a certain output level (Kolstad, 2005). Since total energy use or emissions are capped, unexpected high economic growth and economic output can put a considerable financial burden on the target group, especially if the cost–supply curve of abatement technologies is steep. On the other hand, higher economic growth can provide financial means for investments in emission reduction technologies. These financial implications of the volume targets can only be negotiated in the target setting process in case there is negotiation involved. According to Herzog et al. (2006), this may lead to weaker targets, in order to reduce the uncertainty of total compliance costs for the target group. It must also be mentioned that the (un)certainty of compliance costs also depends on the type of policy instrument that sets the target. For example, emission trading schemes make compliance to the target level more flexible and in effect, reduce the cost uncertainty. Combining volume targets with a so-called safety valve or price cap that sets a limits to the compliance costs in terms of $/$CO_2$, also reduces uncertainty. However, a price cap may compromise the environmental outcome of the policy.

In contrast, both physical efficiency and economic intensity targets reduce uncertainty in compliance costs, compared to volume targets in case of unexpected high growth of activity (Pizer, 2005; Ellerman and Wing, 2003; Kolstad, 2005). Physical efficiency and economic intensity do not limit the total compliance costs in the case of unexpected growth, but due to the nature of the target (total allowable energy use or emissions are conditional on the activity), compliance costs do not increase as fast as is the case with volume targets, thereby reducing the uncertainty. The reduced uncertainty of costs associated with intensity targets may lead to the adoption of more stringent targets (Van Vuuren et al., 2002). Physical efficiency targets and economic intensity targets are less flexible in combination with

[12] There are several restricted methods for benchmarking the energy efficiency. In the so-called full benchmark all comparable installations in the world are involved, and the best standard is defined as the best decile (the 10% best industries); in the region benchmark, the best regions are involved and the average of the best region is defined as best standard; in the best practice method, only the very best in the world is looked at, defining the best standard as a 10% higher specific energy consumption; if previous methods are not feasible, auditing principles will be applied to estimate the potential energy efficiency improvements.

emission trading and are therefore more costly (Dudek and Golub, 2003).

The major advantage of economic targets is that they take cost aspects into account, which provides target groups with a better sense of total compliance costs and the associated risks. The ability-to-pay targets set limits to total compliance costs and uncertainty is fully reduced. Profitability targets guarantee that firms only have to implement measures that are economically attractive from a private perspective. Profitability targets do not however control the total compliance costs. The total compliance costs or at least the total initial investment may increase drastically at high energy prices. An important advantage of socio-economic targets is that theoretically it leads to the lowest total costs for the society as a whole. However, for individual companies the burden may be substantial if a large part of the energy savings or emission reduction potential is present within these companies. This is even a bigger issue in a situation where standards are not applied internationally.

6.4. Public relevance

Volume targets expressed as energy use and CO_2/GHG emission targets in absolute terms have the advantage that they can be easily aggregated across sectors and borders, traded and used in offset schemes. These targets therefore provide insight in the contributions of individual firms or sectors to achieve national or international climate change commitments. All other types of targets do not have the advantage of being in accordance with current international climate commitments under the Kyoto Protocol. Though, physical efficiency targets are proposed for post-Kyoto commitments in global sector agreements. Economic targets (specific costs) in combination with binding caps are sometimes proposed as alternative international climate commitments. Economic intensity targets on the country level are also propagated as new climate change commitments, especially for developing countries. An important advantage of economic intensity targets is that they fit well with the public interest in decoupling environmental pressure from economic output (Herzog et al., 2006).

6.5. Relevance for industry

Both physical efficiency targets and profitability targets are extremely important to industry, making them more acceptable compared to other target types. Profitability targets fit well with industry practise of cost–benefit analysis. The pay back period, net present value and internal rate of return are often used to decide upon important investments. The positive characteristic of physical efficiency targets is that they fit well with industry practice where costs (i.e. energy) are tracked per unit (Elliot, 2003). Physical efficiency targets are however not suitable for sectors with a large variety of products or for sectors that do not produce physical products but services (Phylipsen et al., 1998). A good denominator to measure the output of a firm must be available. That is straightforward for manufacturing firms, but more difficult in diversified corporations producing a large variety of goods, e.g. electronic industries like Philips. An advantage of physical efficiency and economic intensity targets is that they do not emphasize a decline in the total emissions such as volume targets do, making them acceptable among firms. Physical efficiency and economic intensity targets can also be described as performance targets, which not only avoid the suggestion of limiting growth but even have a positive motivational effect (Pizer, 2005). Economic intensity targets also fit with industries nature to minimize costs (energy input) against economic output.

6.6. Potential for comparison

An important drawback of volume targets, expressed in an absolute target value for energy use or CO_2/GHG emissions is that they do not allow for a comparison of the stringency of the target and the energy performance among companies in the same sector nationally or internationally. Physical efficiency targets in absolute terms as used in benchmarking policies, facilitate the comparison of the performance and the stringency of the target among similar companies in a sector, nationally and internationally. Physical efficiency improvement targets in relative terms can compare the (annual) progress that firms have yet to make. This most likely explains the preference for using efficiency improvement targets in relative terms above absolute target values for efficiency, which are only suitable to compare the performance of similar companies. However, a true comparison is only possible if all the conditions like historic improvements, production volume and structure, base year, etc. are equal. Economic intensity targets are difficult to compare across countries since they lack the ability to reflect structural differences (Phylipsen et al., 1998). Economic targets allow for a comparison of the financial efforts that companies are making in order to limit energy use; however, regional differences in energy prices must also be taken into account.

6.7. Complexity

The nature of volume targets is very straightforward: these targets prescribe that a company or a sector is not allowed to use more than a certain amount of energy or emit more than a certain amount of CO_2/GHG at a fixed point in the future. Volume targets can easily be used for any type of firm. However, setting the target level or the allocation of emission allowances can be a much more complex procedure requiring many other parameters. Other types of targets are more complex and their complexity increases the uncertainty to the environmental outcome, raises the costs for monitoring and verification and eventually could lead to the adoption of less stringent targets. The evaluation of the physical energy efficiency targets requires more data collection than volume targets, especially in the case of more complex targets such as the EEI. There are also several problems associated with economic intensity targets. One problem is that the economic activity must be adjusted for changes in the product price and inflation in order to make economic intensity comparable over time. Second, there are many options in measuring economic activity (see Farla, 2000). Value added is strongly influenced by changes in product prices, feedstock prices, etc. The influence is smaller for the value of shipments (Phylipsen et al., 1998). Economic targets are relatively complex targets. Many different input parameters like the energy price, life time of the investment, discount rate determine the profitability of the investments, the specific mitigation costs or the ability-to-pay and in the end the environmental outcome.

7. Conclusions

The primary goal of this paper was to develop a taxonomy for SMART targets for limiting industrial energy use and associated GHG emissions. The developed taxonomy distinguishes volume reduction targets, physical efficiency improvement targets, economic intensity improvement targets and economic targets, including socio-economic targets, profitability targets or ability-to-pay targets. We have shown that targets can be established by different actors, with various scopes, under different compliance regimes and with different target coverage.

The second aim of this paper was to analyse the current use of SMART targets in industrial energy and climate policies. Targets are used in various policy instruments and measures such as limited number environmental permits, a wide range of voluntary or negotiated agreements and a substantial number of emission trading schemes. The number of policy instruments and measures that use economic targets continues to increase.

The third aim of the paper was to evaluate the various types of targets. Volume targets guarantee a relatively certain environmental outcome, have high public relevance and are not as complex as other types of targets. Physical efficiency targets lead to environmental improvements with a high level of integrity, allow for (international) comparison of the environmental performance among firms or sectors and have high relevance for industry. Economic targets combine various advantages such as a high level of environmental integrity, high certainty of compliance costs and high relevance for industry. Economic intensity targets do not have clear advantages compared to other type of targets.

Energy or climate policies that allow industries to comply with the targets through various mechanisms, e.g. CO_2 cap and trade systems or the Canadian 'Regulatory Framework for Air Emissions', can reduce risks and uncertainties regarding the environmental outcome, environmental integrity and compliance costs, but may result in more complex compliance procedures.

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