Energy Policy 34 (2006) 200–211

ENERGY POLICY

www.elsevier.com/locate/enpol

How much market do market-based instruments create? An analysis for the case of "white" certificates ☆

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Available online 17 September 2004

Abstract

Among the diverse economic instruments to foster energy efficiency (EE) and climate protection, tradable certificates have been investigated for renewable energy, and the EU directive on an emissions-trading scheme for CO_2 certificates has been approved in 2003. In contrast, tradable energy efficiency—or "white"—certificates have only lately been considered as a market-based tool to foster EE as compared with standards and labelling, for example. Theoretically, there is little doubt about the advantages. In practice, however, some fundamental problems arise. Critical issues are the design of an efficient artificial market for white certificates, its compatibility with the European emissions-trading system, the identification of a suitable target group for an EE obligation and the measurement of energy savings as compared with a reference use of energy. We use the theoretical framework of transaction cost economics to elaborate these issues. We conclude that transaction costs and investment specificity will restrict markets for white certificates in practice. Long-term contracts rather than spot trade will be the prevailing form of governance for EE investments.

Keywords: Tradable certificates; Energy efficiency; Transaction cost

1. Introduction and theoretical framework

A number of economic and other instruments are under discussion to contribute to energy-saving and climate protection objectives nationally and internationally, and among them are different forms of tradable certificates. Tradable green certificates for renewable energy, for example, have been investigated and tested for some time now, and the EU directive on an emissions-trading scheme (EU ETS) for CO_2 certificates has been approved in 2003. In contrast, tradable white certificates have only been lately celebrated as a market-based tool to foster energy efficiency.[1]

In this paper, we concentrate on the design of a system for tradable white certificates and on conditions for guaranteeing the efficiency of the instrument. Theoretically, a tradable certificate system will allocate energy efficiency (EE) activities to the sites with minimum marginal costs, provided that number of conditions and principles are met. This includes additionality of the investment as compared with a business as usual development, measurability (or accuracy of information) of the realised savings, and

☆ A much earlier version of this paper was presented at the ECEEE Summer Study 2003. Ole Langniss held a Marie-Curie Grant of the European Union (Contract MCFI-2000-01067) at the time of undertaking the research reported in this article. Barbara Praetorius is funded via the interdisciplinary research project "TIPS—transformation and innovation in power systems", funded by the German Ministry for Education and Research (BMBF). We would also like to thank the ECEEE team, Adriaan Perrels and an anonymous reviewer for helpful comments.

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[1] One exemption is Rader and Norgaard (1996) who adverted to the applicability of the certificate concept to DSM rather early.

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doi:10.1016/j.enpol.2004.08.025

practicability of the whole trading and verification system.

In practice, this involves a number of challenges, most of them related to informational or transaction cost. For example, before issuing the white certificates, the factual savings have to be determined. For this purpose, a reference energy use or baseline without the efficiency measure has to be determined and compared with the energy consumption after implementing the efficiency measure. Aspects, which need to be considered here, include the problems and consequences of uncertainty and of leakage (e.g. site-specific "energy savings" by closing down a plant and importing the energy from abroad), but also the treatment of the so-called no regret measures. A further issue is the integration of white certificates with the EU-wide emissions-trading system. Altogether, the assessment of potentially efficient designs for a system of tradable white certificates requires a careful analysis of the problematic issues and approaches to manage them in practice.

Theoretical starting point for our reasoning is the concept of transaction cost economics (TCE). TCE focuses on the choice of an appropriate organisation of economic activities (in other words: an appropriate governance structure). It starts from the observation that information is not complete per se and that the human capacity to process information is limited. Improving access to and processing of information is related to costs. In consequence, human behaviour is guided by the rule of *satisficing* rather than optimising. In this regard, TCE has the same roots like other scholars of the New Institutional Economics. People intend to act rational but are bounded by their own capacities of thinking. Economic actors hence take their decisions on the basis of imperfect information (Richter and Furubotn, 1999, p. 510) and bounded rationality (Simon, 1957, p. 198). The pure existence of bounded rationality and imperfect information opens the door for the so-called opportunistic behaviour, a rather euphemistic term for dishonesty, fraud and malice (Williamson, 1987). To summarise, any investment is inevitably related to additional costs, the so-called transaction costs. Transaction costs can take one of two forms, inputs of resources or a margin between the buying and selling price of a commodity in a given market (Stavins, 1995, p. 134). The former are the direct costs of carrying out a transaction, i.e. costs for search, information and contracting, while the latter can be regarded as the opportunity costs incurred when an efficiency-enhancing transaction is not realised (Milgrom and Roberts, 1992, p. 604) The latter, also referred to as governance costs, stand very much in focus of TCE. We therefore extend our concept of investment and include transaction costs as part of the initial investment in an EE measure.

An important concept of TCE is the notion of *investment specificity*. Investments can be *specific*, i.e. related to high sunk cost, or *generic*, i.e. easily transferable to another application. According to TCE, specific investments allow a more efficient production than more generic investments (Williamson, 1987). The higher the specificity of the investment the more will these efficiency gains occur only in the specific transaction. Thus, specific investments are characterised by quasi-rents, which can be derived from this investment in comparison with its next profitable application. For example, once an insulation has been fixed to a certain building, it delivers energy savings to the building user but cannot easily (if at all) be transferred to another building. It thus loses most of its initial market value, and the asset owner depends on sufficient payments by the building user to be able to recover his sunk costs and to realise the quasi-rent of the specific investment. The investment is highly specific to the transaction between the energy service provider and the building user. In contrast, a CHP-plant has a more generic character since it is more easily transferable to other applications.

Investments specific to a certain transaction thus open the door for opportunism: the quasi-rent is on risk for opportunistic behaviour by a transaction partner (a customer, a retailer, etc.). This "partner" may threaten to refrain from buying the output of the investment and thus be able to appropriate at least a part of the quasi-rent. In anticipation of this danger, the asset owner has an incentive to invest in more generic assets with lower quasi-rents on risk but possibly also lower efficiency.[2] Alternatively, an appropriate governance structure may be established to safeguard the quasi-rents of specific investments against opportunistic behaviour (Williamson, 1987). In so doing, efficiency gains due to the specific investment can be realised, which is comparatively profitable for both transaction partners and increases overall social welfare as compared with low-efficiency investments.

To conclude, the extent of specificity of investments is a main determinant for the choice of appropriate governance mechanisms. The *higher* the specificity the more an efficient governance will be characterised by patterns of hierarchies. Hierarchies can take the form of a firm or a regulation. They allow for cooperative and intentional adaptations to changes in the environment, are connected to stricter accounting and auditing as administrative controls, and hence imply a lower incentive intensity. By contrast, *low* specificity of investments allows for pure governance by markets and thus to benefit from theoretically optimal incentive structures by profit-maximising behaviour. At the same time, the choice for an appropriate governance structure is not a choice exclusively between either markets or

[2]Note that the term"efficiency" is used here in a generic meaning, not exclusively meaning energy efficiency.

hierarchies, but may also lead to a hybrid governance structure with elements from both "sides".

In the case of EE investments, an additional opportunity for opportunistic behaviour may exist. As long as EE investments are not fully competitive by themselves, the external benefits of these investments due to reduced environmental impacts and higher security of supply need to be remunerated; otherwise the investments would not take place. Public regulations are a way to internalise these positive externalities, either by means of financial assistance or by compulsory efficiency standards. In the latter case, the state may appropriate the extra-rents accruing from the EE investment by altering the regulation. For example, if the regulation is phased out untimely or unexpectedly, the EE investments will lose at least some of its value as the investor loses the expected extra-benefits from the regulation. To avoid such a situation or its anticipation (which would be a disincentive for future investments), a reliable 'regulatory contract' (Birkenbach et al., 2001) is needed as a tool to provide comparable safeguards against opportunistic behaviour from the side of the state.

In the following chapters, we use the above theoretical framework to discuss tradable certificates for EE measures for the case of grid-bound energy.[3] We assess the existing tradable certificate schemes in the UK and Italy. The ultimate aim is to derive criteria to be met by and to develop recommendations for a successful and useful tradable white certificate schemes.

Critical issues for successful schemes are a functioning market mechanism, the adequate choice of a target group, and measurement of the efficiency improvement as compared with a reference case:

- *Market mechanism:* Which criteria guarantee that an (artificial) market for certificates really becomes competitive? Does the specificity of EE investments allow for efficient governance by markets for tradable certificates? Will trading be characterized by spot markets or by rather anti-competitive long-term over-the-counter contracts? Which minimum market size is needed, and which are the conditions regarding the tradability of the certificate that have to be met?
- *Target group:* What aspects have to be considered when deciding on the obliged parties? Who should be obliged to purchase certificates? Are electricity suppliers the right target group, or should fuel and heat suppliers be addressed, or the consumer himself?
- *Additionality and measurability:* Which EE technologies should be eligible for certificates? What exactly is an energy efficient technology? A narrow definition might ease measuring problems but at the same time reduce incentives for innovation approaches.

[3]The concept of tradable certificates has only been applied for grid-bound energy. However, it is per se also suitable for non-grid-bound energy.

Many of these challenges are similar to those involved by the project-based mechanisms (Joint Implementation and the Clean Development Mechanism) within the Kyoto Protocol. We therefore refer to the respective discussions whenever useful.

The rest of the paper is organised as follows: To begin, a brief review of the design of tradable certificate schemes in Italy and the UK is given, and experience with Renewable Portfolio Standards recently implemented in a number of countries is analysed. Secondly, aspects of a successful design of a tradable certificate scheme for EE are discussed. In the final chapter, we summarise and discuss our findings.

2. International experiences

This section describes briefly two regulations with trading possibilities recently implemented in Europe. A short overview is given about trends in regulation for promoting renewable energies in Europe and the US.

2.1. The British energy efficiency commitment

The British "Energy Efficiency Commitment" obliges all electricity and gas suppliers to save a total of 62 TWh of fuel-standardised energy by 2005 against 2002 (Obligation, 2001). This obligation only covers the energy supply to households. Only suppliers with more than 15,000 customers need to meet the obligation. The total target is broken down into individual obligation in relation to individual market shares. Generally, all EE measures need to get approval by the regulator to achieve eligibility for the regulation scheme. The regulator has defined a number of standard EE measures that he accepts for fulfilling the obligation. The energy savings of these standard measures are quantified, too. Thus, energy savings need not to be metered measure-by-measure, which allows for reducing transaction costs quite considerably. New and innovative schemes not contained in the list of standard measures are still possible but require independent verification. Subsidised supply of compact fluorescent lamps is accepted as an eligible measure to a limited extent per served customer.

As another restriction, at least 50% of the EE measures must take place in low-income households. Thus, the market for eligible EE measures is differentiated in low-income households and others. To encourage energy services, they will be rewarded with an additional 50% on top of the sum of energy savings of the single EE measures content of the energy service. Energy services are thereby defined as consisting of at least two different single EE measures with a single customer, and need to incorporate individual customer consultancy. The total energy savings over the lifetime of the EE measure will be awarded to the energy supplier initiating the EE measure. Future savings will be thereby discounted.

The regulation does not provide tradable certificates. However, some limited flexibility is provided in two ways:

- Energy savings may be traded. The regulator needs to approve the trade.
- Individual obligations may be also traded. Again, this trade needs official approval.

Thus, anonymous trade is not possible but only bilateral over-the-counter trade. Spot trade is not possible either. This trade will thus allow equalising marginal costs to a certain extent but it will not provide any public information on prices of EE. In summary, we may characterise this system as a rather conventional command-control policy with some restricted flexibility concerning fulfilment of obligations.

2.2. Italian EE certificate trading

In April 2001, two Ministerial Decrees set targets of reducing consumption of electricity by 18.6 TWh/a and of gas by 15.1 TWh/a, respectively, against a business-as-usual scenario in the period of 2002–2006 (AEEG, 2002). This relates to between 5 and 15% of the Italian Kyoto target (Malaman and Pavan, 2002). The national target is apportioned to electricity and gas suppliers with more than 100,000 customers according to their individual market shares. This translates to 22 obliged gas suppliers and 8 obliged electricity suppliers. At least 50% of the individual obligations need to be covered by EE measures in the electricity sector and gas sector, respectively, whereas the remaining obligation may be fulfilled with any other EE measures. This means that, for instance, savings of heating oil are eligible too. There exists a comprehensive illustrative list of eligible EE measures. The regulator issues certificates to obliged electricity and gas suppliers as well as to energy saving companies (ESCO) who have paid for EE measures. Trade of certificates does not need official approval. Trade can take any form from bilateral contracts to transactions on anonymous markets. A penalty is imposed in case of non-compliance. Obliged suppliers are able to recover costs of EE measures through an additional fixed element in the variable tariffs. The regulator has fixed this recovery rate at a level of 0.017€ for every kWh saved energy. This guaranteed cost recovery (= guaranteed minimum price for certificates) is only granted to obliged suppliers and up to the amount of their individual obligation but is not granted, e.g. to independent ESCOs. The difference between the guaranteed cost recovery and the costs of the EE measure is obliged suppliers' profit.

The success or failure of the trading scheme cannot yet be evaluated. The original deadline for compliance (May 2003) was shifted to the year 2004. At least, the saving targets set by the Italian regulator seem to be achievable since they are small compared with the energy-saving potential (Pagliano et al., 2003). As long as actual specific energy saving costs are below the pre-set recovery rate, the scheme behaves as a Minimum Price Standard. In this case, independent ESCOs are disfavoured compared with the obliged suppliers since they cannot attain this minimum price themselves. With energy-savings costs above the guaranteed minimum price, obliged parties will prospectively, as much as possible, try to fulfil their quota with EE measures that do not decrease their individual sales. Due to rather limited number of market actors we expect bilateral trade rather than anonymous spot market trade with certificates if any at all.

2.3. Renewable portfolio standards

To increase the market penetration of renewable energies, a range of regulations have been implemented in various European countries in recent years (Haas et al., 2004). Mainly, price regulations have been established. However, a number of countries (Italy, Sweden, United Kingdom) have recently turned to quantity regulations with tradable certificates (also called Renewable Portfolio Standards or quotas); others abandoned or postponed such plans (Austria, Denmark, the Netherlands). A tender system can be currently found only in Ireland.

Fifteen US states have recently implemented Renewable Portfolio Standards, often (but not always) as a component of electricity reform, These are Arizona, California, Connecticut, Hawaii, Illinois, Iowa, Maine, Massachusetts, Minnesota, Nevada, New Jersey, New Mexico, Pennsylvania, Texas and Wisconsin (DSIRE, 2002). Some first success stories are beginning to emerge from Arizona, Texas and Wisconsin, and there is much hope for the standards in Massachusetts, Nevada and New Jersey. However, to date, few of these policies have been operable for more than a year and several have not yet begun. The experiences with the Texan Standard show that certificates are mostly jointly traded in the framework of long-term contracts (Langniss and Wiser, 2003). The Renewable Portfolio Standards in several of these states do not contain very strong provisions and may do little to instil confidence in the renewable energy industry.

In summary, we see a mixed picture of different renewable energy regulations in the USA and Western and Central Europe. Even though widely discussed, Renewable Portfolio Standards have only been recently implemented in a number of countries and states. It is important to note, that in spite of the broad attention Renewable Portfolio Standards have gathered in the scientific and political discussion, no general trend towards Renewable Portfolio Standards can be seen to emerge. Countries are still establishing new price regulations (in Europe, e.g. Austria, France) and others have postponed or cancelled plans for Renewable Portfolio Standards (in Europe, e.g. Austria, Denmark and the Netherlands). Growth of electricity-generating RE has predominantly taken place in countries with price regulations. Tender systems have been established only in a few countries and have mostly ended now.

2.4. Conclusions from existing experience

Our review of implemented certificate schemes shows that white certificate schemes are still in their infancy. White certificate schemes still need to prove their feasibility and efficacy. So far, experience suggests that real-world schemes will get rather complex. Moreover, the theoretically perfect markets for certificates are not likely to be the relevant model of the resulting governance for introducing more energy efficiency,but rather a trend towards regulation and hierarchy. Indeed, the two national white certificate schemes implemented up to now feature many elements of traditional regulation. This applies particularly to the British scheme with only a few elements which provide flexibility through trading. The setting.up of the Italian scheme is promising. However, it discriminates independent ESCOs against incumbent electricity and gas suppliers.

3. Design of a tradable certificate scheme for energy efficiency

3.1. Basic elements of a tradable certificate scheme

A scheme for supporting EE with a tradable certificate scheme comprises of several elements. First, a quantitative overall target needs to be set, either in absolute terms or relative to energy consumption. Secondly, the participants of the trading scheme have to be determined and obliged to take part. In a market environment for grid-bound energy like electricity, natural gas and district heating, the obliged parties can be energy generators, distributors, suppliers, or energy consumers themselves. Thirdly, a regulation is needed to translate the overall target to individual targets for the obliged parties. Fourthly, EE measures eligible to fulfil the respective obligation need to be defined carefully while considering a number of possible restrictions. There are several options for measures eligible for an EE scheme:

- The scheme may admit only certain EE measures (e.g. energy-efficient light bulbs) and exclude others.
- The scheme may admit exclusively hardware installations eligible or also software measures such as information campaigns or customer education.
- The scheme may be constrained to EE measures, which economise on the same *energy carrier* the obliged party is supplying.
- Finally, the scheme may be restricted to EE measures related to the customers of the individual obligator to fulfil its target.

These design options have to be weighed against their respective benefits and disadvantages. Economic theory suggests that wider the definition of eligibility is, lesser the restrictions are and lower are the costs to fulfil an obligation. On the other hand, a lax definition of EE may result in limited comparability and measurability of EE measures and their effects and thus reduce the efficacy of the regulation *or* increase transaction cost for monitoring the EE measure.

Obliged parties prove the fulfilment of their target by presenting certificates that attest a certain amount of saved energy. These certificates are tradable, which allows obliged parties either to fulfil their obligations by own EE measures or to buy certificates from others. Here, some restrictions may apply: First, the regulator may control trade by asking for official approval for any transaction. Secondly, similar to the regulations for the flexible mechanisms of the Kyoto Protocol, the parties obliged to increase EE may only be allowed to cover a certain share of their individual obligations by certificates bought on the market; this would force the obliged parties to undertake own EE measures in any case. Finally, a monitoring system needs to be established to issue and track certificates and to impose penalties when an individual obligation is not fulfilled.

Here again, transaction costs and the market size are under question; the more complex the administrative procedure for trading and monitoring is, the higher the share of the target that is to be covered “at home”, the smaller the certificate market will be, and the more the system will resemble a traditional command and control policy.

3.2. Specificity of EE investments

Participation in a tradable certificates scheme depends on the specificity of the respective EE investments. EE investments can be specific or generic towards an investor’s commercial transactions. Specificity arises when EE assets are designed for specific purposes, e.g. production equipment which is of no or limited use for any other product. Specificity also arises when EE investments are solely undertaken to supply certain purchasers. For example, when a manufacturer runs a factory which supplies different goods for a number of customers, an enhancement of the factory buildings isolation would have the same low specificity as the rest of the production equipment. In contrast, enhancing a factory building, which houses highly specific assets, creates an investment with a higher specificity. Similar conclusions apply to efficiency improvements in production technologies and energy supply technologies. Specific investments may also occur as a consequence of regulation: when EE investments are undertaken to fulfil a specific regulatory obligation; assets may be highly specific when the investment would create no or only small benefits to the investor in the absence of the respective regulation.

TCE assumes that the higher the specificity of an asset, the larger are in general opportunities to raise efficiency. The reasoning is that assets which are adapted to specific purposes may be driven more efficient. Analogously, this applies to EE: EE potentials can thus be assumed the largest with highly specific assets. Also, the higher the targets in reducing energy consumption are, the more specific the EE investments get. Or putting it the other way round, early energy savings may be achieved with less specific investments than more ambitious ones.

Finally, without appropriate governance structures to safeguard quasi-rents from EE investments, these investments will not take place. Rents from specific investments are on risk with a governance based on pure, unregulated markets; in consequence, less EE investments than efficient ones will be undertaken as compared with a situation with some regulation. Thus, opportunity costs occur, which we have earlier defined as one type of transaction costs, as governance costs. This TCE reasoning adds an important explanatory (yet similar) aspect to the existing discussion on barriers to EE investments, which focuses on the prohibitive effect of high upfront investments (Vine et al., 2003) and on the phenomenon of short payback periods stipulated by investors in EE measures (see DeCanio, 1993; Blumstein et al., 1980; Fisher and Rothkopf, 1989; Koomey, 1990; Levine et al., 1995; Stern and Aronson, 1984; Bhattacharjee et al., 1993).

However, so far, the above arguments only apply to commercial energy consumers. Commercial energy consumers consume energy to accomplish their business. Energy costs are part of their overall production costs. Against that, private households consume energy as part of their overall final consumption. Their extra income from reduced energy costs cannot be acquired by any transaction partner. It is not the threat of losing this extra income but search and information costs which detain households from investing in energy-efficient appliances. Thus, their own EE investments may not be analysed with TCE.

This picture changes when energy services or technologies are supplied rather than pure energy. Investments in the household sphere will make supply of the energy service more efficient. These investments may be highly specific or not in respect to the transaction between the household and the energy service provider. Examples for a highly specific investment are EE light bulbs. Albeit EE light bulbs themselves can be applied generic (their value is the same in the next best application), the energy service supplier's costs of dispensing the bulbs are sunk costs. Thus, this part of the investment is entirely specific. Another example of specific investments is consultancy, which is needed to identify the most appropriate EE measures. Standardised analysis and proposal formats help keep investments in consultancy rather generic. However, a more ambitious energy saving target requires individual consultancy, thus raising the specificity of the investment.

Introducing energy service companies (ESCOs) commercial energy applications may reduce the specificity of EE investments. Take again the example of consultancy, The costs of gathering information as to how to achieve best EE may be highly specific to a single consumer of energy. Against that, an ESCO might use the gathered information also with other customers thus their investment is less specific. The benefits from economies of scale may thereby exceed by far the benefits from the reduction of specificity in this case. There are also technical means to reduce specificity of EE investments, e.g. movable CHP plants.

To summarise, the analysis of specificity of EE investments reveals that the higher the EE target is, the less appropriate a pure governance by markets will be. A more hierarchical governance allows more specific investments, as it preserves the owner from the risk of sunk cost; thus more EE is achievable. Hierarchical (and not market) governance is crucial to secure transactions between those parties who are investing in EE and those who are paying for the EE measures in the end. Even when regulation creates a market, the actors on this market will tend to establish forms of hybrid governance with some elements of hierarchy such as long-term contracts. This hybrid governance will soften the ongoing "high-powered incentives" (Williamson, 1987, p. 90) to act efficiently that are constituent for pure markets. ESCOs may reduce the specificity of EE investments into search and information. EE policy should be thus targeted also on establishing ESCOs.

3.3. Transactions in EE tradable certificate schemes

A tradable certificate scheme promises a higher degree of autonomy of decision, combined with prospected

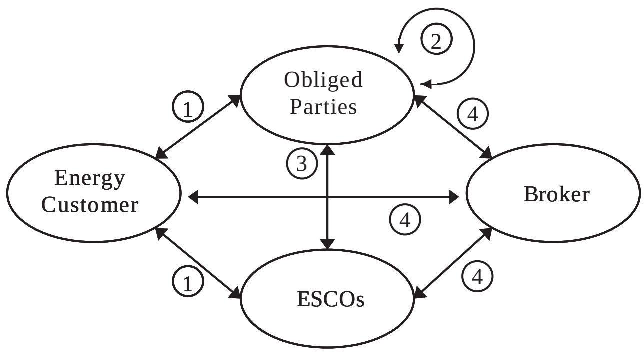

Fig. 1. Possible transactions of certificates induced by tradable certificate schemes.

lower overall costs. This makes it more appealing to the obliged parties than other types of EE regulations (Langniss, 2003, p. 68 ff). However, the above discussion of design features and particularly of possible restrictions made already clear that a tradable certificate scheme for EE does not allow per se for more freedom to obliged parties than conventional command-and-control regulations or alternative instruments.

So, what kinds of relations are then established through a certificate scheme? To answer this question with the help of the TCE, we need to take a closer look on the additional transactions of certificates induced by a tradable certificate scheme for EE (Fig. 1). These are

1. Transactions between obliged parties (i.e. in most cases the energy supplier) or ESCO and users of the EE measures, i.e. the energy service customer.
2. Transactions between obliged parties for the purpose of trading certificates.
3. Transactions of obliged parties with (non-obliged) ESCO, which are independently accomplishing EE measures and marketing EE certificates.
4. Transactions of any trading party with broking intermediaries.

With transactions of the first type, energy consumers will trade certificates to obliged parties. To generate certificates, the energy consumers need to invest. Thus, these transactions are crucial for achieving EE through a regulation based on tradable certificates. As we have shown, EE investments may be highly specific to this transaction. So, these transactions tend to be governed by hierarchy, for example, through long-term contracts, to secure the investments; otherwise, they would not take place. Such long-term contracts, however, limit the freedom of obliged parties once they entered in long-term contracts. The obliged parties may instead choose to invest themselves in EE on the level of the final consumer. In this case, a *contract* needs to fix that certificates arising from the EE investment are to be transferred to the investor. Hence, this option will not change the need to secure specific investments with long-term commitments.

Alternatively, a *regulation* may assign the certificates to the investor. In that case, no transaction of certificates needs to take place. This option is equal to a situation where obliged parties fulfil their regulatory obligation by entirely internal business. This type of allocation of certificates seems to be more appropriate to reality. Investments by energy companies or ESCOs are usually regarded as crucial to achieve more EE on the demand side. The regulation may even allocate the entire energy savings generated prospectively over the lifetime of the EE investment to the investor already at the time of investment. After commissioning the EE investment neither the energy consumer nor the obligor would then need to prove whether the energy savings actually took place. This implies a shift of risks from the investor to the regulator. Such an approach is only feasible in the case of measures with proven effectiveness and little opportunities for fraud like building insulation. However, as in both cases, i.e. certificate transactions governed by hierarchy or assigning directly certificates to the investor, the resulting governance does not provide an additional permanent incentive for the efficient use of energy, as pure markets would do.

Trade of certificates between obliged parties will take place as long as marginal costs for EE are different for different obliged parties. Given a functioning market for certificates, such a trade system ensures that marginal costs of the regulation are the same for all obliged parties. Economies of scale may be realised by bundling demand for EE.

In this context, it is worth to note that energy suppliers as obliged parties will also incorporate their opportunity cost due to decreased energy sales in their calculus of marginal costs of EE. Thus, acquiring certificates on the certificate market may be more favourable than realising EE with own consumers even if direct costs of EE with own customers are lower than certificate prices on the market. As long as the marginal income from energy sales (i.e. price minus variable costs) is larger than the difference between the price of certificates purchased on the market and the costs of generating certificate with own energy customers so long will it be more favourable to purchase certificates on the markets. We thereby assume that certificates available on the market do not lead to decreasing sales of the specific energy supplier. In other words, it is not a make-or-buy problem but rather about realising energy savings with own customers versus energy savings with other customers. Such calculation does, however, not consider external benefits from increased customer loyalty which may occur with EE programmes with own customers. Note also, that the same EE measure may be less costly with existing customers than with others since existing information channels and knowledge about customers can be used in a favourable way.

In the case where no specific assets are involved, i.e. when the generation of EE certificates is based on non-specific investments, trade on markets will be the prevailing and appropriate form of governance. As soon as specific investments are involved, the governance will tend to a more hierarchical form with long-term contracts softening the continuous incentives to act efficiently. However, investors ready to take over some risk might still choose to market certificates on the spot market. The same might be true if obliged parties generate certificates exceeding their own obligation to a small amount of their obligation.

The ESCOs are in a similar position as obliged energy suppliers. This is particularly true for their relations towards energy consumers. Specific investments of ESCOs need to be secured by some hierarchical governance or long-term contracts as well. The possibility to trade EE certificates creates an additional income flow. Thus, ESCOs get less dependent on equipment users' payments. As far as specific investments are involved, certificate transactions tend to hierarchical governance. However, as we discuss below, the often small share of certificate trade may restrict the benefits from the additional income as well as the need for more hierarchical governance.

Brokers may facilitate trade of certificates and they may act as risk takers as well. Regarding the second issue, the same applies to brokers as was said on obliged parties and ESCOs, depending of course also on the broker's readiness to take risks.

One should be aware that income from certificate sale may only represent a small or even negligible part of the total income from EE investments. As long as energy consumers themselves undertake EE investment, income from reduced energy bills is often sufficient to cover the extra costs of the investment, as many calculations on feasible EE potentials show (Fisher and Rothkopf, 1989; Koomey, 1990). But even when energy suppliers as investors are concerned, benefits, for example, from strengthened customer loyalty may entirely offset the costs of EE investment and reduced energy sales. Securing income from selling certificates may be thus less crucial than opening more opportunities for market governance. In these cases, an EE regulation of any kind is rather a means to raise awareness on EE potentials than a costly obligation. Tradable certificate schemes have thereby the advantage that market prices of certificates will reveal the low total costs of EE policy.

3.4. Establishing the reference use of energy and verification of energy savings

Issuing certificates for EE efforts presumes that these efforts can be measured. The underlying problem is not trivial. Two crucial issues are to be solved both in theory and in practice. First, what is the *baseline* for an EE improvement, and secondly, how can energy savings be *metered*?

The process of establishing the reference situation of monitoring and determining the realised energy savings involves a number of methodological issues. To determine the energy savings resulting from an EE activity, the eventual energy consumption has to be compared with a reference situation (or *baseline* or *business as usual*) without additional saving efforts. But what exactly is the baseline, and which reference technology should be accepted and which time frame applied? How can energy savings be identified as supplemental or additional to a reference development? What are the relevant boundaries for a project, and how can leakage effects be minimised? The related practical problems are multiple.

First and foremost, the reference use of energy is, by definition, *counterfactual* and thus imposes considerable *uncertainty* on the determination of investment additionality. The calculation of the baseline scenario hast to take into account likely changes in relevant regulation and laws, the trend in autonomous efficiency improvements and changes of other basic variables such as the development of markets for products of the project (Michaelowa and Fages, 1999, p. 173).The baseline hence includes assumptions which inevitably create a certain level of uncertainty. A study conducted for eastern European countries estimates the range of counterfactual uncertainty for the case of greenhouse gas emission reductions, related to the underlying assumptions used for the respective baseline calculation, to be as high as $\pm 55\%$ for cogeneration projects and $\pm 35\%$ for demand side projects (Parkinson et al., 2001).

Secondly, the relevant *system boundary* has to be determined and will vary, depending on the respective EE measure. The system boundary also establishes the reference case for determining the energy savings of the EE measure. For example, end-use efficiency measures could have an impact on the related upstream levels and should ideally be considered. This, however, is not practical because it would impose prohibitively high information or transaction cost (Gustavsson et al., 2000).

The third issue, directly related to the system boundary, is the risk of producing *leakage* (Parkinson et al., 2001). When the system boundary is set too narrow, energy savings may be overstated. Take for example a total demand of generation capacity of about 100 MW. When the system boundary is drawn around a generation plant with a capacity of 100 MW, and this plant is replaced by an efficient cogeneration plant with a capacity of 50 MW, half of the demand will be covered by generators outside the system boundaries, regardless of their respective efficiency properties. Also, a number of indirect effects may be disregarded, such as an autonomous reduction in demand. In this example, both effects would lead to overstating real energy savings.

A fourth and crucial issue (and criterion) is the practicality and cost-effectiveness of a baseline methodology. Both establishing a relevant baseline and monitoring energy savings implies cost to the project developer and also to the government or regulator. The cost of monitoring and evaluation has been estimated to amount to about 5–10% of the project budget, which of course depends on many factors and assumptions (Vine and Sathaye, 2000). Relative transaction costs are even higher in the case of small-scale energy saving technologies and of private households (DIW, 2003). Even worse, as it is in the case of demand side management programmes, indirect behavioural and positive spill-over effects are difficult to calculate and distinguish from an autonomous development without the EE measure (Gustavsson et al., 2000). Both factors encourage investors to overstate the actual savings with the aim to receive and sell more white certificates. It also stimulates the appearance of free riders, i.e. participants that would also have invested in an EE project in the absence of the tradable white certificates scheme. These effects increase the regulatory expenses on the side of government for monitoring the accuracy of reported energy savings.

A further aspect to be discussed is the issue of how to treat no-regret measures in the baseline determination. By definition, no regret means that no additional cost are implied, as the investment is entirely or even more than covered by the related energy savings. However, these investments did not take place without the EE programme. The additionality criterion hence needs a careful definition in order not to inhibit such investments.

The above (and further) issues have been addressed for the case of the flexible mechanisms of the international climate protection regime (Kyoto Protocol) in a large body of literature in the last few years (e.g. Violette et al., 2000 for baselines in the case of energy efficiency; for baselines in general, see Ellis and Bosi, 2000; Bosi, 2000; Ellis, 2001, 2002; Bode et al., 2001). Therein, a number of methods have been suggested and may mostly be applied to the case of EE certificates.

Regarding the *system boundaries*, it is mostly recommended to use project-based baselines (Michaelowa and Fages, 1999; Parkinson et al., 2001). The reason is that the degree of uncertainty is significantly higher in the case of sectoral or country-related baselines because of the uncertainty related to assumptions other than project-related variables. Even then, however, a number of issues need to be treated. For example, there may be a difference between baselines for a *replacement investment* as compared to *additional capacity*. In the first case, the EE investment may be compared with an existing plant or appliance it is supposed to replace. However, as long as the respective replacement investment is in time anyway, it is difficult to evaluate if the investment is more than business as usual-progress in terms of the energy efficiency. In the second case of additional capacity, the baseline needs to reflect the technology that would otherwise be implemented.

For a regulator, the appropriateness of such an individualised baseline approach via reference technologies chosen by the investor is difficult to assess, and information/transaction costs are high. The regulator may therefore decide to offer a standardised approach. For example, a certain *performance benchmark* for individual or a class of appliances or technologies could be determined against which all newly implemented technologies are then evaluated with regard to the energy savings. Such a benchmark could be either the average *existing*, a *historical state,* or the *state of the art* of EE technologies. Laurikka (2002) shows that such *relative* baselines or performance benchmarks indicate in a more realistic manner the energy savings obtained. The argument is that benchmarks help to avoid uncertainties about the activity level of a project. In any case, standardisation allows for significant reductions in the related transaction cost.

Last but not least, a number of more or less practicable and accurate *monitoring* methods have been suggested (Vine and Sathaye, 2000, p. 200). Here, again, a standardised approach may ease the supplemental burden of transaction cost.

The major issue remains the *level of transaction cost* involved by the method chosen. The accuracy of complex but expensive methods has to be weighed up against the inaccuracy of rough but cost-saving methods. Here, it is probably necessary to accept a *satisficing* description of a baseline and to define appropriate control mechanisms (for example, comparison groups or scientific studies about likely baselines). Another approach would be to offer standardised baselines for project categories and to offer a possibility to submit individual baselines in case that the standard does not fit to the project.

To summarise, both theoretical considerations and practical experiences show that assessing the success of EE measures in quantitative terms involves high transaction costs. Standardised baselines and monitoring procedures may alleviate the measurability problem. In the case of the flexible mechanisms, the approach is two-pronged: first, to define a set of *principles* to be followed, i.e. the project proposal has to outline the expected emission reductions in a transparent and comprehensible way on a project basis, and secondly, to allow for *simplifications* in the case of defined project categories, for example, small-scale projects. Analogous standards and procedures may be introduced in the case of the tradable white certificates scheme.

3.5. Who should be obliged?

In this section we will discuss some aspects related to the choice of who should be obliged to fulfil a certain reduction of energy consumption. In a market environment for grid-bound energy, e.g. electricity, natural gas, and district heating, the obliged parties can be either energy generators, distributors, suppliers or energy consumers themselves. To date, energy suppliers seem to be the most appropriate choice for some reasons, adapted from (Wuppertal Institut für Klima Umwelt Energie, 2002):

- The obligation will support the development of energy suppliers to become providers of genuine energy services.
- This way the incentive structure for energy suppliers changes from maximisation of energy sales to maximisation of energy service sales.
- Supply companies have direct access to energy consumers so that they can build their EE efforts upon existing customer relations and existing infrastructure.

Against that, energy *generators* have generally only poor knowledge on the demand side. Since distribution remains a natural monopoly even in liberalised markets, distributors do not act under competitive pressure. Incentives to lower costs are thus smaller in comparison with those parties acting under competition. An obligation directly imposed on the final energy consumer would directly motivate changes in consumption patterns. However, energy supply companies can be regarded as a more appropriate addressee, as they experience lower transaction costs both with the regulator and the obliged parties, and also may realise economies of scale with respect to information and specific knowledge on EE measures as compared with the individual consumer. A synthesis between the options of obligating consumers vs. obligating suppliers is to obligate the customers but relegate the obligation by default to energy suppliers; this can be found in the Swedish proposal for a certificate trading scheme for electricity from renewable energy sources (Elcertifikat, 2001). A right to apply for fulfilling the obligation themselves remains with customers. This will allow particularly large energy customers to realise own EE potentials and benefiting from the regulation.

Regulations tend to focus on grid-bounded energy since these sectors have been regulated traditionally for reasons of natural monopolies. Thus, public influence in this sector has been large. However, there is no reason for not widening the obligation for EE to non-grid-bounded energy carriers like heating oil or even transport fuels. Particularly concerning the heat market, this would avoid distortion of markets which otherwise occur when solely natural gas or district heating suppliers are obliged.

3.6. Market features and compatibility with emission trading

Policy instruments with tradable certificates to balance obligations are particularly favourable compared with command-control policies, if large differences exist between individual marginal costs of EE measures of obliged parties. The larger these differences the larger will be the induced trade of certificates. Presumably, as differences in marginal costs get larger, the wider the scope of the regulation in terms of accepted EE measures and spatially becomes.

Conventional economic theory suggests that a market will produce the best results

- when the traded goods are homogenous,
- when information is perfectly transparent to all market actors (buyers, sellers, intermediates), and
- when a certain critical minimum market size is exceed.

These three features are all interlinked. The EE certificates should best be issued in the same form and size, for example, denoting "100 kWh saved" or—in the case of an environmentally focussed certificate—denoting one tonne CO_2 saved and so on. The critical market size is the easiest achieved when there are not too many different products and parallel markets. Perfect information allows for access of many buyers and sellers to a market (including international actors), and information (i.e. transaction) costs are minimised when goods are homogenous and when transparency is guaranteed for. It is for these reasons that stock exchanges are usually quoted closest to a perfect market.

In the case of EE certificates, these aspects also have to be considered. First and most important, defining and issuing a homogenous certificate is indispensable. This simultaneously eases the information problem and thus the transaction cost involved on the level of the certificate market. Eventually, the larger the market size is the more EE measures are included into the trading scheme *or* the larger the obligation (or quota) for the target group is being set. Hence an international EE certificate scheme with many participating countries would give the most benefits. However, as experiences with the flexible Kyoto mechanisms or a uniform European regulation to promote renewable energy shows, it is very difficult to establish such an international regime. It is thus very unlikely that an international EE certificate scheme will occur in the nearby future. Reversely, there is leeway for national schemes. All kinds of EE measures with all kinds of energy consumers should be awarded with the same type of homogeneous certificate. No different partial obligations for certain technologies should be imposed since this would differentiate markets and thus reduce competition. Such an approach would leave decisions for the most cost-efficient EE to the market for certificates. Yet, one may apply innovative approaches and appliances e.g. specific energy services with additional certificates to acknowledge difficulties arising for new products and entrants into the market place.

To date, EE is for the most part being appreciated as a contribution to reducing the environmental impacts of energy use, and more specifically to the reduction of emissions, particularly of green house gas emissions (GHG). Many countries see EE as part of their climate protection strategy. One may therefore ask why an additional tradable certificates regime should be established. Furthermore, any plan to introduce efficiency-oriented tradable permits as discussed in this paper has to take into consideration existing or planned market-based policy instruments for EE, because it otherwise runs the risk of creating a parallel market. This may result either in double transaction cost for the participating actors when the markets are completely separate, or in a smaller market size for one of the two trading mechanisms.

In Europe, an emission-trading scheme (ETS) for greenhouse gas emissions will be implemented by the year 2005. However, some serious shortcomings of the ETS have to be stated. In particular, it is limited to about half of the industrial energy consumers but will not address households, trade and the other half of industry. Moreover, the motivation to promote EE goes beyond reducing emissions from energy generation. It also includes enhancing security of supply and raising the competitiveness of industry by increasing the overall efficiency. It is therefore still reasonable to introduce a white certificate scheme even in the presence of a European emission-trading scheme. A possible adjustment may be to exclude those parties from an obligation within the white certificate scheme who are already obliged within the ETS. However, one has to be aware that potential benefits from a white certificate scheme against other mechanisms get smaller or even disappear. This is because the emission market is differentiated, the size of the market for white certificates is only sub-optimal and information costs of involved parties are increasing.

4. Conclusion

In our paper, we discussed conditions and criteria to be met for a successful system of tradable white certificates. Based on the theoretical framework of TCE we elaborated these issues as well as the related problems. Theoretically, a regulation to promote EE via tradable white certificates allows equalising the individual marginal costs of all obliged parties. Moreover, bundling of demand for EE can activate potential economies of scale. This also creates opportunities for ESCOs and hereby promotes a shift from traditional energy suppliers towards energy service providers. Moreover, an innovative approach such as a white certificate scheme may help to overcome political barriers, which more traditional forms of policies and regulations are facing. Compared with traditional command and control regimes, the flexibility provided through the trading mechanism might be particularly appealing to those who get obliged and have to bear the burden.

To date, an EE-oriented scheme of tradable certificates cannot be discussed without considering the EU emissions-trading scheme, which will be introduced by 2005. Within this scheme, EE will also play an important role. It would not make sense to create two parallel markets for EE certificates on one hand, and for CO_2 certificates on the other hand, because transaction cost involved would be much higher. However, the above reasons for promoting EE should also make clear that the benefits of EE go beyond pure mitigation of GHG. Thus a GHG policy alone does not provide sufficient incentives to mobilise all the benefits that come with EE. A specific policy to foster EE is thus grounded in the specific bundle of public benefits linked to enhanced EE. The same arguments apply for promoting renewable energies.

Given a number of conditions being met, including the standardisation of baselines and monitoring to reduce transaction cost on the side of the government, a tradable certificate scheme allows to promote EE without additional burden for public budgets. At the same time, the total burden on customers of achieving a predetermined level of EE may be minimised. However, our analysis based on TCE as well as experiences from green certificate trade reveals that long-term contracts rather than spot trade are likely to be the prevailing form of governance for EE investments reducing considerably the potential benefits of a tradable certificate scheme.

Tradable certificate schemes are not the only policy option promising the benefits of markets. Tenders organised by public authorities and financed out of general surcharges may serve the same purpose as well. Considering transaction costs, such an option might even distort less competition between larger and smaller suppliers than certificate trade.

To conclude, more research and further experiences with white certificates is needed for a proper assessment of this policy option. The nature of many EE measures, in particular their transaction and investment specificity, restricts the potential market in practicse. The definition of eligible EE measures also remains a challenge in terms of balancing transaction cost reductions related to a wider, flexible formulation of eligibility vs. the risk of stimulating business as usual rather than really additional EE measures. The definition problem is also reflected in two realised regulations on EE comprising also flexible market elements.

Reference

AEEG (Autorità per l'energia elettrica e il gas), 2002. Proposte per l'attuazione dei Decreti Ministeriali del 24 Aprile 2001 per la promozione dell'efficienza dnergetica negli usi finali. Milano.

Bhattacharjee, V., Chicchetti, C.J., Rankin, W.F., 1993. Energy utilities, conservation, and economic efficiency. Contemporary Policy Issues 11, 69–75.

Birkenbach, F., Kumkar, L., Soltwedel, R., 2001. Wettbewerbspolitik und Regulierung—Die Sichtweise der Neuen Institutionenökonomik. In: Zimmermann, K.F. (Ed.), Neue Entwicklungen in der Wirtschaftswissenschaft. Heidelberg, pp. 217–275.

Blumstein, C., Krieg, B., Schipper, L., York, C., 1980. Overcoming social and institutional barriers to energy conservation. Energy 5, 335–349.

Bode, J.-W., de Beer, J., Blok, K., 2001. An initial view on methods for emission baselines: iron and steel case study. OECD/IEA Information Paper, Paris. Download at www.oecd.org/env/cc or http://www.ghgprotocol.org/projectmodule.htm

Bosi, M., 2000. An initial view on methods for emission baselines: electricity generation case study. OECD/IEA Information Paper, Paris. Download at www.oecd.org/env/cc or http://www.ghgprotocol.org/projectmodule.htm

DeCanio, S.J., 1993. Barriers within firms to energy-efficient investments. Energy Policy 21 (9), 906–914.

DIW, 2003. Leitfaden für die klimaschutzpolitische Bewertung von JI- und CDM-Projekten. Projekt im Auftrag des Umweltbundesamts, Berlin.

DSIRE, 2002. Database of state incentives for renewable energy. http://www.dsireusa.org/. Status October 28, 2002.

Elcertificat, 2001. Handel med elcertifikat. Ett sätt att främja el från förnybara energikällor (Trade with electricity certificates. A means to support power from renewable energy sources) SOU (Statens Offentliga Utredningar), Stockholm, 2001,p.77.

Ellis, J., 2001. An initial view on methods for emission baselines: cement case study. OECD Information Paper, Paris Download at www.oecd.org/env/cc or http://www.ghgprotocol.org/projectmodule.htm.

Ellis, J., 2002. Developing guidance on monitoring and project boundaries for greenhouse gas projects. OECD/IEA Information Paper, Paris Download at www.oecd.org/env/cc or http://www.ghgprotocol.org/projectmodule.htm.

Ellis, J., Bosi, M., 2000. Emission Baselines. Estimating the Unknown. OECD and IEA, Paris Download at http://www.ghgprotocol.org/projectmodule.htm.

Fisher, A.C., Rothkopf, M.H., 1989. Market failure and energy policy. A rationale for selective conservation. Energy Policy 17,4, 397–406.

Gustavsson, L., Karjalainen, T., Marland, G., Savolainen, I., Schlamadinger, B., Apps, M., 2000. Project-based greenhouse-gas accounting: guiding principles with a focus on baselines and additionality. Energy Policy 28, 935–946.

Haas, R., Eichhammer, W., Huber, C., Langniss, O., Lorenzoni, A., Madlener, R., Menanteau, P., Morthorst, P.-E., Martins, A., Oniszk, A., Schleich, J., Smith, A., Vass, Z., Verbruggen, A., 2004. How to promote renewable energy systems successfully and effectively. Energy Policy 32 (2004), 833–839.

Koomey, J.G., 1990. Energy efficiency choices in new office buildings: an investigation of market failures and corrective policies. Ph.D. Thesis. Energy and Resources Group, University of California, Berkeley.

Langniss, O., 2003. Governance structures for promoting renewable energy sources. Dissertation, Stuttgart, Lund.

Langniss, O., Wiser, R., 2003. The Texan renewable portfolio standard. An early assessment. Energy Policy 31, 527–535.

Laurikka, H., 2002. Absolute or relative baselines for JO/CDM projects in the energy sector? Climate Policy 2, 19–33.

Levine, M.D., Koomey, J.G., McMahon, J.E., Sanstad, A.H., 1995. Energy efficiency policy and market failures. Annual Review of Energy and the Environment 20, 535–555.

Malaman, R., Pavan, M., 2002. Energy efficiency certificate trading. Food for thought from a recently launched Italian scheme. Presentation. IEA-DSM Workshop on Energy Efficiency Certificate Trading, Milano. April 17, 2002.

Michaelowa, A., Fages, E., 1999. Options for baselines of the clean development mechanism. Mitigation and Adaption Strategies for Global Change 4, 167–185.

Milgrom, P., Roberts, J., 1992. Economics, Organisation and Management. Englewood Cliffs, NJ.

Obligation, 2001. Energy Efficiency Obligation. Order 2001. Bill 2001 No. 4011.

Pagliano, L., Alari, P., Ruggieri, G., 2003. The Italian energy saving obligation to gas and electricity distribution companies. Proceedings ECEEE 2003 Summer Study, St. Raphael, June 2–7, 2003, pp. 1059–1068.

Parkinson, S., Begg, K., Bailey, P., Jackson, T., 2001. Accounting for flexibility against uncertain baselines: lessons from case studies in the eastern European energy sector. Climate Policy 1, 55–73.

Praetorius, B., Ziesing, H.-J., 2001. Quotenmodell für Kraft-Wärme-Kopplung mit handelbaren Zertifikaten. Zeitschrift für Energiewirtschaft 25(2), 107–123.

Rader, N., Norgaard, R., 1996. Efficiency and sustainability in restructured electricity markets. The Renewable Portfolio Standard. The Electricity Journal 9(7), 37–49.

Richter, R., Furubotn, E., 1999. Neue Institutionenökonomik, second ed. Tübingen.

Simon, H.A., 1957. Models of man. Social and Rational, New York London.

Stavins, R., 1995. Transaction costs and tradable permits. Journal of Environmental Economics and Management 29, 133–148.

Stern, P.E., Aronson (Eds.), 1984. Energy Use: the Human Dimension, New York.

Vine, E.L., Sathaye, J.A., 2000. The monitoring, evaluation, reporting, verification, and certification of energy-efficiency projects. Mitigation and Adaption Strategies for Global Change 5, 189–216.

Vine, E.H.J., Eyre, N., Crossley, D., Maloney, M., Watt, G., 2003. Policy analysis of energy efficiency and load management in changing electricity businesses. Energy Policy 31, 405–430.

Violette, D., Mudd, C., Keneipp, M., 2000. An Initial View on Methods for Emission Baselines: Energy Efficiency Case Study. OECD/IEA Information Paper, Paris Download at www.oecd.org/env/cc or http://www.ghgprotocol.org/projectmodule.htm.

Williamson, O.E., 1987. The Economic Institutions of Capitalism. New York.

Wuppertal Institut für Klima Umwelt Energie. (Ed.), 2002. Bringing Energy Efficiency to the Liberalised Electricity and Gas Markets. Study with support of the European Commission, Wuppertal.