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Abstract

White certificate schemes mandate energy companies to promote energy efficiency with flexibility mechanisms, including the trading of energy savings. A unified framework is used to estimate the costs and benefits of the schemes implemented in Great Britain in 2002, in Italy in 2005 and in France in 2006. “Negawatt-hour cost” estimates reach €0.009 per kWh saved in Great Britain and €0.037 per kWh saved in France, which compares favourably to energy prices in those countries. Moreover, the benefits of reduced energy bills and CO_2 emissions saved exceed the costs, thus white certificate schemes pay for themselves. Overall, the policy instrument is cost-effective and economically efficient.

A closer look at the differences among countries provides general insights about the conceptualization of the instrument: (i) compared to utility demand-side management, to which they are related, white certificate schemes provide more transparency about energy savings, but less transparency around costs; (ii) the substantial efficiency discrepancy between the British scheme and its French counterpart can be explained by differences in technological potentials, coexisting policies and supply-side systems in these countries; (iii) the nature and amount of costs influence compliance strategies. Notably, if energy suppliers are allowed to set their retail price freely, they tend to grant subsidies to end-use consumers for energy efficient investments.

Keywords : White certificate schemes, Energy efficiency, Effectiveness, Cost-effectiveness, Social efficiency.

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Analyse coût-bénéfice des dispositifs de certificats blancs

Résumé

Les dispositifs de certificats blancs obligent les opérateurs énergétiques à encourager l’efficacité énergétique en associant des mécanismes de flexibilité, notamment l’échange d’économies d’énergie certifiées. Cet article utilise une méthodologie commune pour estimer les coûts et bénéfices des dispositifs mis en œuvre en Grande-Bretagne en 2002, en Italie en 2005 et en France en 2006. Le coût du « négawatt-heure » est estimé à 0,9 c€ par kWh économisé en Grande-Bretagne et à 3,7c€/kWh économisé en France, soit un coût inférieur au prix des énergies dans ces pays. Ces dispositifs sont efficients, dans la mesure où les bénéfices issus de la réduction de la facture énergétique et des émissions de CO_2 évitées sont supérieurs aux coûts.

Un examen plus détaillé des différences entre pays apporte des éléments généraux sur la conceptualisation de l’instrument : (i) comparés aux politiques américaines de *Demand-side management* qui les ont inspirés, les dispositifs de certificats blancs apportent plus de transparence sur les économies d’énergie réalisées mais moins de transparence sur les coûts ; (ii) la différence substantielle d’efficience entre les dispositifs britannique et français s’explique par des différences de gisement technologique et de système de production d’électricité, ainsi que par des politiques préexistantes ; (iii) la nature et le montant des coûts influence les stratégies des opérateurs énergétiques. En particulier, lorsque les fournisseurs d’énergie sont autorisés à fixer librement leur prix de vente, ils ont tendance à offrir des subventions aux consommateurs finaux pour des investissements dans l’efficacité énergétique.

Mots-clés: dispositifs de certificats blancs, efficacité énergétique, efficacité, coût-efficacité, efficience.

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Keywords

White certificate schemes, Energy efficiency, Effectiveness, Cost-effectiveness, Social efficiency

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Introduction

White certificate schemes are a new policy instrument aimed at accelerating the diffusion of energy efficient technologies[1]. They are characterised by three main components: (i) an obligation is placed on energy companies (hereafter "the obliged parties") to achieve a quantified target of energy savings; (ii) energy savings are certified using standardized calculations that minimize transaction costs; (iii) certified energy savings can be traded so as to allow obliged parties to fulfil their target (Bertoldi and Rezessy, 2008). The combination of a binding constraint (non-compliance is financially penalized) with flexibility provisions like trading places this instrument in the family of market-based instruments, which have received much emphasis in the field of environmental policy (Labanca and Peerels, 2008).

White certificate schemes have been implemented in Great Britain in 2002, in Italy in 2005 and in France in 2006. Whilst meeting the common definition above, they have been adapted to national contexts, with different energy market structures and regulations. According to early *ex post* comparisons, this variety of designs leads to country-specific outcomes (Eyre *et al.*, 2009; Mundaca and Neij, 2009, Bertoldi *et al.*, 2010) that complicate the analysis in two ways. First and foremost, it blurs any judgement about whether white certificate schemes are cost-effective and economically efficient. Second, it prevents from empirically validating the stylized representation established by theoretical works, that tend to define white certificate schemes as a hybrid subsidy-tax instrument, by which energy companies provide rebates for energy efficient durables that are recovered through increased energy prices (Bye and Bruvoll, 2008; Giraudet and Quirion, 2008; Oikonomou *et al.*, 2008; Peerels, 2008; Sorrell *et al.*, 2009). Overall, the understanding of white certificate schemes is far from complete and requires extensive evaluation.

Useful insights can be gathered from the retrospective examination of demand-side management (DSM) programs, in which the rationale for white certificate schemes is firmly rooted (Waide and Bucher, 2008; Eyre *et al.*, 2009). DSM has been implemented in the United States during the mid-1980s as part of integrated resource planning, aimed at optimizing the electric system on both the supply and demand sides. DSM obliged electric utilities to promote electricity load management, as well as to provide information and financial incentives for energy efficiency investments to end-use customers (Gillingham *et al.*, 2006). The assumption behind these programs was that energy utilities can influence final energy consumption through commercial relationships, and are hence the best suited agents to tap the scattered potentials for energy efficiency. Such potentials are particularly present in the commercial and residential sectors.

[1] Theoretically, white certificate schemes aim at energy conservation, i.e. both energy efficiency improvements and changes in energy consumption patterns (Gillingham *et al.*, 2006). In practice, most of the measures target energy efficiency (e.g. lighting, heating, insulation) while only a few "soft measures" target behavioural change (e.g. training for construction workers in France).

Yet since the end of the 1990s, the European Union has pushed through major reforms to liberalize electricity and gas markets[2], which changed the motivations for energy efficiency policies compared to DSM imposed to public vertical monopolies. On the one hand, the unbundling of vertically integrated utilities removes incentives for energy efficiency along the whole value chain: transmission and distribution businesses have no hold over end-use consumers to implement programs, while generation and retail businesses (which often remain integrated) are not willing to reduce demand. On the other hand, the introduction of competition on retail supply presumably creates an incentive for suppliers to provide energy service for commercial differentiation (Vine *et al.*, 2003; Eyre *et al.*, 2009; Langniss and Praetorius, 2006). The use of flexibility options, in particular the trading of white certificates, is supposed to accompany this evolution of energy business models.

The primary concern about evaluating white certificate schemes is to assess their cost-effectiveness and social efficiency[3], which are the most common criterion for comparing outcomes of energy efficiency policies (Gillingham *et al.*, 2006; Goulder and Parry, 2008). This calls for the quantification of two sensitive variables: (i) the energy savings specifically induced by the scheme, dependent upon assumptions on the reference situation and its trend over time (Boonekamp, 2005; Thomas, 2009); (ii) the costs of energy savings, a significant share of which is borne by obliged companies, thus not necessarily subject to disclosure and transparency.

In DSM, both sets of data were to be reported by utilities to the U.S. Energy Information Administration (EIA). This allowed for extensive evaluation of utility programs, although different econometric specifications gave rise to a debate about whether self-reports underestimate (Joskow and Marron, 1992; Laughran and Kulick, 2004), overestimate (Horowitz, 2004) or reasonably estimate (Auffhammer *et al.*, 2008; Vine and Kushler, 1995) cost-effectiveness. White certificate schemes make different cases for the two types of data. Achieved energy savings are generally (but not exclusively) certified on *ex ante* basis by standardized calculation, which increases transparency and eases data aggregation. The point is much more problematic with regards to costs. One of the principles of white certificate schemes is to mandate performance rather than means, and monitoring of obliged parties' expenditures goes against this principle. Moreover, in liberalized energy markets, cost is sensitive information that energy suppliers are reluctant to disclose. Cost information is therefore not reported and readily available, hence must be specifically evaluated. The market price of certificates may appear to be meaningful data for this task,

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[2] This is according to the European Commission directives of 1996 regarding the internal electricity market (Directive 96/92/EC) and 1998 regarding the internal gas market (Directive 98/30/EC).

[3] The following social efficiency assessment concentrates on environmental benefits. A range of other collective benefits, such as health improvement or employment in the energy efficiency industry, might accrue, but they are not addressed here.

but in fact this rarely turns out to be the case. First, according to economic theory, the market price of white certificates equals the marginal cost of compliance, yet the average cost is the most appropriate for estimating the total cost of the scheme. Second, its significance as a marginal cost indicator depends upon the liquidity in the white certificates market, which is high in Italy but very low in France and almost absent in Great Britain (Mundaca *et al.*, 2008; Eyre *et al.*, 2009). Lastly, it is even more problematic if the market for white certificates can be manipulated by a few dominant actors or influenced by a cost recovery mechanism, which is the prevailing situation in Italy, as will be discussed later.

The goal of this paper is to overcome those limitations and estimate the costs and benefits of white certificate schemes under a common framework for the three countries. For this purpose, it builds on existing evaluations of the achieved periods[4] in Great Britain (Lees, 2005, 2008; Mundaca and Neij, 2008) and provides comparable results for France and also – at least partly – for Italy. This enables to provide answers to elementary evaluation questions such as: *Are white certificate schemes cost-effective and economically efficient? How do heterogeneous country characteristics explain differences in national outcomes? What type of strategies do obliged energy companies develop to cope with compliance costs?*

The paper is organised as follows. Section 2 outlines the basic differences among national schemes that are relevant to the study. Section 3 assesses the effectiveness of energy savings. Section 4 concentrates on the costs borne by obliged energy companies. Section 5 balances total costs with benefits to assess the social efficiency of the scheme. Section 6 moves on to the interpretation of the costs to enlighten the strategies developed by energy companies to comply with their obligation. Section 7 concludes.

1. Main differences in national designs

Differences across white certificate schemes have been widely discussed (Bertoldi and Rezessy, 2008; Eyre *et al.*, 2009; Mundaca *et al.*, 2008; Oikonomou *et al.*, 2007; Vine and Hamrin; 2008) and only the differences that are relevant to the study are stressed hereafter. In addition to the common objectives presented above, national schemes can have particular focuses. Notably, the British scheme is designed to address fuel poverty and imposes a certain amount of energy savings to be promoted towards low-income households. Nevertheless, outcomes related to country-specific objectives are not detailed here.

[4] These refer to the EEC1 (Energy Efficiency Commitment, 2002-2005) and EEC2 (Energy Efficiency Commitment, 2005-2008) schemes in Great Britain, TEE (Titoli di Eficienza Energetica, 2005-2012) in Italy and CEE (Certificats d'économies d'énergie, 2006-2009) in France. In Great Britain, the superseding CERT scheme (Carbon Emissions Reduction Target, 2008-2011) includes important changes compared to EEC2, such as a doubling of the target, a switch from kWh to CO_2 savings accounting and a new definition of the priority group (Lees, 2008).

1.1 Scope of the obligation

The energy market liberalization process has been achieved in Great Britain in 1998, in Italy in 2004 and in France in 2007. Electricity and gas markets can now be regarded as fully unbundled in these countries. In this context, the nature of the obligation holder is a prominent element of scheme differentiation. In Great Britain and France, the obligation is borne by energy suppliers, who have close relationships with final consumers and favour direct actions. The British scheme is limited to electricity and gas suppliers whereas in France, all type of end-use energy suppliers are covered, except gasoline.[5]. In Italy, the obligation is borne by electricity and gas distributors operating on local and regional networks. Such actors have barely any commercial interest to support consumers that are not directly their own. In France[6] and Italy, some non-obliged parties are allowed to promote energy savings and sell them to obliged parties, thus creating an additional supply of white certificates. This possibility is coupled in these countries to the organisation of *over the counter* markets, and even a *spot* market in Italy. In Great Britain white certificates exchanges are legally allowed, but discouraged in practice by the absence of organised markets and the need for a preliminary agreement by the Regulator.

In addition to the type of obliged parties, their numbers differ across the three countries. In Great Britain, six electricity and gas suppliers compete within an oligopoly, with market shares on the household sector ranging from 11% to 32% (Lees, 2008, p.21). In France, around 2,500 energy suppliers hold an obligation. Provided that both electricity and gas markets are concentrated and still dominated by historical operators (EDF and GDF SUEZ, respectively), this large number should not distract from the fact that the array of major players is reduced. In Italy, the obligation is placed on 30 electricity and gas distributors of very different size. Being regional monopolies, they do not compete on energy distribution, but they might face oligopolistic competition on the markets for white certificates (Oikonomou *et al.*, 2009).

Lastly, whereas the British scheme covers solely the household sector, the scope in other countries is extended to all end-use sectors, except installations covered by the European Union Greenhouse Gas Emission Trading System (EU-ETS) in France. However, in all schemes, deemed measures focus on the household sector, where saving accounting methods can be more easily standardized. Basic technologies are identical across countries and cover the most relevant potentials for energy efficiency (e.g. efficient lighting, efficient appliances, efficient heating systems and insulation). There are 37 standardized actions in Great Britain, 22 in Italy and 170 in France.

[5] This was the case during the first period assessed in this paper. The next period, starting in 2011, will extend the obligation to gasoline distributors.

[6] Insofar as this does not increase their revenue, which deters the participation of pure ESCOs

1.2 Metrics of the obligation

National targets and standardized energy savings are formulated in very different units across countries. The main difference between national portfolios, however, lies in the certificates issuance, in particular in the assumptions made for energy savings calculation on conventional unitary consumption, conventional lifetimes and discount rates. Savings are expressed similarly in France and Great Britain (EEC2) in kilowatt-hour (kWh) of end-used energy saved, accumulated over average lifetimes of 20-30 years and discounted at close rates of 4% and 3.5%, respectively. In Italy, annual savings are calculated in ton of oil equivalent (toe) of primary energy, and issued over a fixed lifetime of five years (eight years for insulation measures as an exception). For purpose of comparison, efforts were made to express each target in the normalized unit of the French scheme. The main assumptions made throughout the paper are summarized in the Annex (Table A1).

The French 2006-2009 target is 54 TWh of end-use energy, accumulated over the average lifetime of the measures and discounted at 4%. In Great Britain, the quantitative obligation of the EEC2 period was 130 TWh of cumulated energy savings fuel standardized, discounted at 3.5%. When converted *ex post* in their original fuel units and appropriately discounted at 4%[7], energy savings reach 192 TWh, thus 64 TWh/year for the three years of EEC2. In Italy, one preliminary task is to convert annual savings of primary energy in toe into lifetime end-use savings in kWh. First, a 2/3 ratio is used to convert primary savings into end-use savings, following Eyre *et al.* (2009). Second, savings are accumulated assuming an eight years average lifetime, which reflects the predominance within final realisations of measures with short lifetimes, such as CFLs or water economizers, and the noticeable absence of measures with long lifetimes, such as insulation (see Section 3.2). As such and discounted at 4%, the target covering the 2005-2008 period equals 193 TWh, thus 48 TWh/year (see Annex, Table A2).

2. Energy effectiveness

As a performance-based instrument, the effectiveness of white certificate schemes is measured against the target compliance. Albeit a matter of concern in itself (Mundaca and Neij, 2009), the intrinsic ambition of the target will not be discussed. Target compliance does indeed, however, raise an array of issues that are addressed hereafter.

2.1 Delimitation of energy savings

General effects impacting energy effectiveness

The question as to whether or not the savings considered are fully effective is a heavily debated issue (Geller and Attali, 2005). The most controversial point deals with "free-riders", i.e. beneficiaries from the scheme that would have undertaken energy efficiency measures

[7] Lees (2008, Table A4.4 and personal communication).

even in the absence of the scheme. Some authors find that if they are appropriately accounted for, they reduce the effectiveness of DSM programs by 50% to 90% (Joskow and Marron, 1992; Laughran and Kulick, 2004). Nevertheless, it has also been acknowledged that thanks to usual self-reinforcing technology diffusion patterns, such programs create "free-drivers", i.e. adopters of energy efficient technologies that are not direct beneficiaries of the scheme (Blumstein and Harris, 1993; Eto *et al.*, 1996). By working in the opposite direction, free-drivers and free-riders partly compensate each other (Thomas, 2009).

Another prominent issue is that energy efficiency improvements generate behavioural changes towards increased comfort, e.g. when insulation or boiler replacement measures are followed by setting a higher indoor temperature. Well known as the rebound effect, the gap between observed energy savings and theoretical energy efficiency gains may undermine the effectiveness of white certificate schemes (Giraudet and Quirion, 2008; Sorrell and Dimitropoulos, 2008). Its magnitude will vary with the type of measure (Geller and Attali, 2005) and the type of measure beneficiary, provided that low-income participants are more subject to take back energy savings to increase comfort (Blumstein and Harris, 1993).

It is remarkable that the evaluator of the British white certificate scheme has taken into account most of these effects. Final figures are net from a 20% "deadweight" factor to account for free-riding, and a 15% "comfort increase" factor to account for some rebound effect (Lees, 2008). Such calculations were not possible for other countries, thus will not be considered in the following, so as to allow for cross-country comparison.

Methodological issues in energy savings accounting

In practice, the relevance of energy savings depends on methodological choices such as baseline setting and the type of certification system (Bertoldi and Rezessy, 2008). The baseline for energy savings must be consistent with *business as usual* market projections and the rebound effect inherent in each technology. In all countries, the baseline is set in line with national regulations transposing European directives such as the recent EPBD[8], which guarantees to some extent the additionality of the savings. In Great Britain, the additionality must be demonstrated for all actions by obliged parties. Yet this does not prevent some pitfalls. For instance in France, the baseline used for boilers is a mix of the stock average and the market average, which makes low temperature boilers eligible, in spite of their poor additionality compared to a pure market reference.

The certification system can take several forms, depending on whether savings are measured on a specific or deemed basis and verified on *ex ante* or *ex post* basis. The most

[8] Energy Performance of Buildings Directive 2002/91/EC of the European Parliament and of the Council

favoured system is deemed *ex ante* certification[9], designed to minimize transaction costs. It is well adapted to the targeted field of residential energy consumption, which is a mass market allowing large-scale technological developments. However, it can hardly be applied in the industrial sector (where covered by the scheme, i.e. in Italy and France), where measures are more complex and better assessed by specific engineering calculation. Furthermore, *ex ante* calculation avoids prohibitive transaction costs compared to a case-by-case *ex post* verification, but does not ensure effective energy savings. Effective savings might depart from *ex ante* calculation because of uncertainties such as realisation defects or lifestyle changes, and the deviation is likely to increase over time for measures with a long conventional lifetime (even though savings are discounted). To address this issue, random *ex post* verifications are conducted by British and Italian authorities, on measures that were certified on *ex ante* basis. Such process in Great Britain revealed that insulation measures did not achieve their full saving potential during EEC2, due for example to incomplete cavity wall filling (Lees, 2008). Likewise, there is no clear guarantee about the effective installation and use of the CFLs that have been widely distributed for free in Great Britain and Italy (Bertoldi et *al.*, 2010). In France, some *ex post* verifications are planned but have not yet been put in place. However, the scheme has induced a process of professional labelling for equipment installers, which in theory reduces the case for technical defects.

Overall, next to the dominant deemed *ex ante* system, *ex ante* specific calculations account for 2.4% of certified savings in France (DGEC, 2009), while *ex ante* specific calculations account for 5% and pure *ex post* calculations for 10% of certified savings in Italy (AEEG, 2008).

2.2 Effectiveness assessment

Quantification of the energy savings to target

To date, no penalty for compliance shortfall has been enforced and national targets have been over-achieved in every country[10]. In Great Britain, the three-year objectives of EEC1 and ECC2 were overachieved by 30% and 44%, respectively (Lees, 2005, 2008). In France, the first three-year period was over-achieved by 20% (65 TWh against 54TWh required, according to DGEC, 2009). In all cases, the overachieved energy savings were carried over to the next compliance period. In Italy, where targets must be fulfilled annually (but fully

[9] Uplift factors can be associated to such calculation, for instance for innovative measures such as digital TVs or stand-by savers in Great Britain. Uplifts are deduced from gross calculation by the British evaluator to estimate effective savings (Lees, 2008).

[10] As stated by Mundaca *et al.* (2008), over-achievements against the national objective do not necessarily imply a fulfilment of all individual targets. Indeed, two obliged parties went out of business during the EEC1 scheme and thus fell short of their target. According to the authors, the overall performance can still be interpreted as effective.

assessed in 2012), the first two years led to an over-achievement of more than 90% (Pavan, 2008).

Whereas over-achievements augment policy outcomes, accounting for some actions implemented prior to the schemes may diminish them. It is noteworthy that in Italy, energy savings promoted between the launch of the scheme in 2002 and its effective implementation in 2005 can be used to meet the annual targets, and have actually represented 27% of the savings generated during the first two years (Pavan, 2008). In Great Britain, savings generated under the preceding Energy Efficiency Standard of Performance (EESoP) program[11] were also eligible (with a limit up to 10% of the target boundary though) and represented less than 5% of the EEC1 target (Lees, 2005). Contentious savings from such "early actions" are thus quantitatively limited and those schemes yielded net over-achievements.

In what follows, the effectiveness assessment is limited to energy savings realised against the target. This appears as an imperfect but reasonable indicator of the effectiveness of the schemes, provided that methodological pitfalls lead to an overestimate of unitary savings while neglecting over-achievements leads to underestimating total savings. According to the convergent estimates of Eyre *et al.* (2009) and Mundaca and Neij (2009), savings to target represent 0.6%, 0.3% and 0.14% of the total energy consumption under coverage in Great Britain, Italy and France, respectively.

Nature of effective energy savings

A full assessment of the effectiveness of the schemes requires a close look at the technological nature of the savings. The measures undertaken in the residential sector encompass the bulk of white certificate energy savings, even in countries with a broader coverage[12] (86% in Italy, according to AEEG, 2008; 87% in France, according to DGEC, 2009). National breakdowns depicted in Figure 1 show important differences among countries: insulation dominates in Great Britain, CFLs dominate in Italy and heating device replacement dominates in France. This difference is striking, since the schemes' flexibility in theory attracts obliged parties towards lowest cost measures that might be similar across countries. In fact, current mixes are driven by country specific factors.

[11] The EESoP was an obligation placed on energy suppliers to invest in energy efficiency. It was implemented in 1993 and replaced in 2002 by the white certificate schemes, mandating performance rather than means.

[12] In Italy and France, industrial measures cover generally small shares of white certificates energy savings, due to a long-standing rational use of energy in this sector.

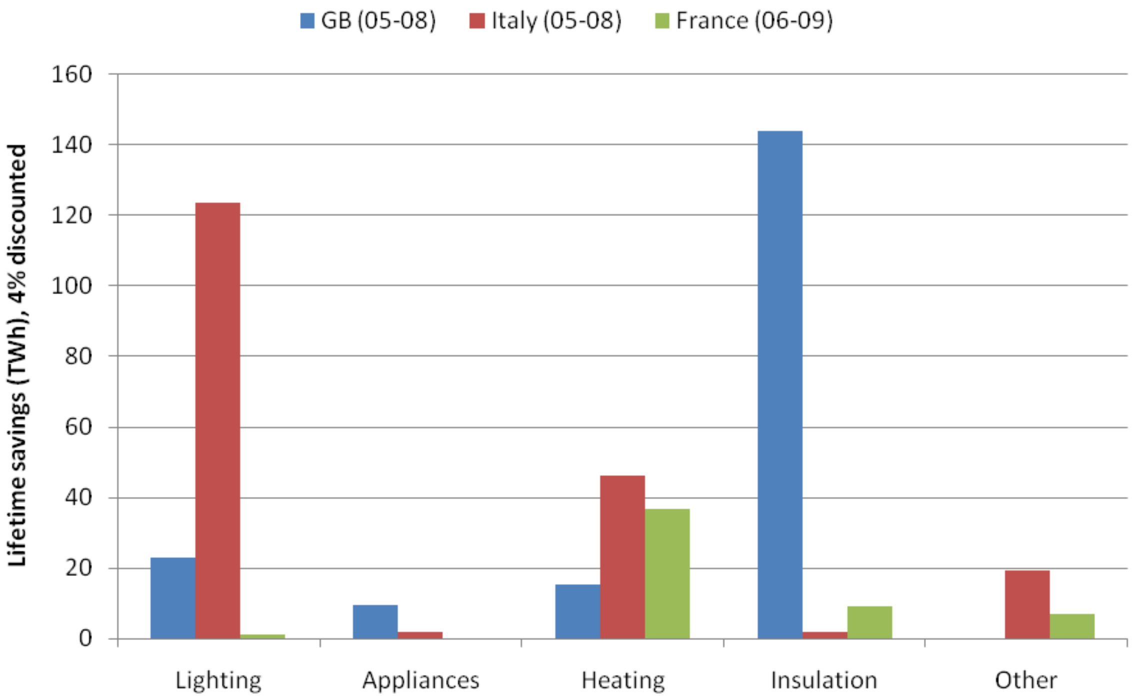

Figure 1. National measures mix (Data: AEEG, 2008; DGEC, 2009; Lees, 2008)

First, there are significant technological differences among countries. Let us consider the case for cavity wall insulation (CWI), that is specific to Great Britain, and solid wall insulation (SWI), that is roughly similar in all countries. The former practice consists in injecting insulating material into a cavity between indoor and outdoor brick walls of traditional British houses, and the latter in hanging panels on indoor walls. CWI incurs lower technological costs than SWI because of lower costs of gross material and the possibility to deploy neighbourhood-scale actions, and therefore generate economies of scale. Moreover, hidden costs due to a higher annoyance of indoor works must be added to the cost of SWI. As a result, the average cost per dwelling is €500 for CWI and €6,000 for SWI (Lees, 2008). This explains that altogether, insulation measures account for 75% of the kWh saved in Great Britain, whereas in France they represent less than 10% of the savings, albeit the largest and most cost-effective potential (Baudry and Osso, 2007)[13].

Moreover, national outcomes are largely driven by country-specific regulatory features. In France, some deemed measures are at the same time eligible to tax credits ranging from 15 to 50% (DGEC, 2009). This means that for many energy efficiency investments, the same invoice can be used by customers to claim for tax credits and by obliged suppliers to claim for white certificates. Therefore, obliged suppliers have intensively advertised for the tax credit scheme while collecting invoices, up to the point that nearly all the measures

[13] In addition to this reference, ADEME estimates the theoretical saving potential in the household sector to be 6,750 TWh (lifetime cumulated and 4% discounted), in which insulation measures account for 60%.

supported by obliged suppliers in the household sector under the white certificates scheme have also benefited from the tax credit scheme. In turn, 20% of the tax credit amounts (2.7 billion Euros in 2009 granted to 1.3 million people, according to MEEDDM, 2010) have granted white certificates. If the tax credit scheme has clearly driven the white certificates scheme, some observers consider that it would not have had such a success without being advertised by energy suppliers in their customer persuasion task, acting indirectly as an information tool (Bodineau and Bodiguel, 2009). This addresses the sensitive question relating to the balance between free-riders and free-drivers. In Italy, CFLs and hot water economizers dominated until recently in the residential sector. The promotion of these "low hanging fruits" has been boosted by the massive distribution of reduction coupons[14]. Considered as a regulatory pitfall, this has been corrected since then (Pavan, 2008). Furthermore, the 5 years lifespan used to calculate standardized savings does not provide the adequate incentive for long-term savings measures. In the case of insulation, notably absent from the Italian scheme, the theoretical lifetime has been set to eight years, which remains far below the values used in Great Britain and France (40 and 35 years, respectively).

3. Costs borne by obliged parties

The costs underpinning effective energy savings are subsequently estimated, in order to complete a full cost-effectiveness assessment.

3.1 Nature of the costs arising from white certificate schemes

Alike DSM programs, the delimitation of costs builds on three principles (Joskow and Marron, 1992; Eto *et al.*, 1996). First, total costs must reflect *the cost of energy efficiency improvements* compared to a reference situation. For measures affecting the built environment like insulation, the reference situation is the absence of energy efficient solution, so that the full capital and installation costs of the measure must be counted. The case is different for equipments like heating systems, where existing device is generally replaced by a new one, chosen among several options differing in terms of energy efficiency performances. Therefore, only the cost differential with the market standard or stock average technology must be considered. Overall, the total cost of energy efficiency improvements from different types of measures is typically lower than the full cost of the underlying capital.

Second, the cost of energy efficiency improvements involves several contributors, mainly customers and obliged parties. Depending on the way obliged parties promote energy efficiency measures, some additional costs can arise. Financial incentives like subsidies or

[14] Obliged distributors were awarded white certificates for the mere distribution of reduction coupons for CFLs and water economizers, without any guarantee about the effective purchase of those equipments, nor their effective installation once purchased.

soft loans are typically based on a share of energy efficiency improvements cost, borne by obliged parties. In contrast, delivering information about energy efficiency programs does not lower the total cost of energy efficiency improvements for customers but generates additional cost for obliged parties. The sum of the total costs of energy efficiency improvements and such additional costs is referred to as the *direct costs* of the scheme.

Third, complying with their obligation might come at a cost for obliged parties, additional to the share of direct costs they already bear. This cost arises from tasks like project development, marketing and reporting (see Annex, Table A3; Lees, 2008, p.88). Whereas direct costs are straightforwardly volume-related, such *indirect costs* may or may not be volume-related. They are very dependent upon the strategies developed by obliged parties to cope with their obligation and cannot be readily derived from the list of achieved measures. Ultimately, the total costs of the scheme are the sum of direct costs plus obliged parties' indirect costs.

3.2 Estimates of the costs borne by obliged parties

Among all the parties bearing costs, obliged parties require a specific treatment. Under white certificate schemes, the tenuous availability of direct and indirect cost data forces the evaluator to make his own assumptions and discuss with energy companies staff members to verify them. This work has been completed by Lees (2005, 2008) for the British scheme and is conducted here for the French scheme. In Italy, it has not yet been done.

In Great Britain, no trading of white certificates occurs[15] and energy suppliers basically grant subsidies to their customers for energy efficiency investments. Their contribution to direct measure costs is a share of either the full capital cost (for insulation and lighting) or the cost differential with the market standard (for heating and appliances), which is calculated using data provided by public authorities[16] about measures costs and stakeholders' respective contributions. Overall, direct costs amount to €1,085 million under EEC2. Indirect costs borne by obliged parties are estimated by Lees from past experiences as 18% of their expenditures on direct measure costs, thus €195 million. A part of those indirect costs has been characterized as "transaction costs" and quantified by Mundaca (2007). The author estimates that under EEC1, efforts dedicated to persuading consumers and negotiating with third parties have borne 8-12% and 24-32% of the total investment cost for lighting and insulation measures, respectively.

[15] In fact some transactions took place under EEC1, but involved negligible amounts. See Mundaca *et al.*, (2008).

[16] The administrator of the scheme is the Office of Gas and Electricity Markets (Ofgem). The policy regulator was formerly the Department of Food and Rural Affairs (Defra), now the Department of Energy and Climate Change (DECC).

In France, trade involves less than 4% of white certificates issued and the strategies of energy suppliers towards customers consist essentially in providing information (diagnosis, advice) and financial incentives (soft loans, rebates), with different weights across the companies investigated. Data are still poorly available and roundtables followed by bilateral interviews with managers from the three main obliged agents[17], namely EDF, GDF SUEZ and Ecofioul (professional association representing fuel oil retailers) were organised to get indications about the relevant sources of costs. Together with the expertise of ADEME and the measures repartition provided by DGEC (2009), this allowed to make further assumptions and finally estimate direct costs to amount to €74 million. Subsequently, an inductive inventory of the potential sources of indirect costs was made. Fixed indirect costs are sunk costs paid to develop news activities in response to the white certificates obligation. This covers material investments like information networks and immaterial investments in energy efficiency training. Variable indirect costs arise from tasks related to the volume of energy efficiency measures, like phone centres and marketing. Each source of indirect cost was then quantified by making assumptions about related labour and capital costs. Overall, the calculated indirect costs amount to €136 million, by 57% variable, which is roughly twice as high as direct costs. All calculations are reported in the Annex (Table A3).

In Italy, the bulk (75%) of white certificates issued are traded on spot and over-the-counter markets, which makes the market price a reasonable proxy for the marginal cost of the scheme to energy distributors. According to Pavan (2008) and AEEG (2008), the average exchange price of white certificates is €60/toe over the period of fully operating markets (2006-2008). Integrating this over the 2005-2008 period's primary energy target (as defined in the Annex, Table A2) yields a total obliged parties' cost of €216 million. One might expect the fixed level of cost recovery to maintain the white certificate price artificially high, given the inexpensiveness of underlying dominant measures (CFLs, water economizers) [18]. Therefore, this calculation tends to overestimate costs.

3.3 Cost distribution among obliged parties

Table 1 shows that the costs borne by obliged parties in France are around six times lower than in Great Britain, for a target more than three times smaller. As a result, cost-effectiveness to energy suppliers is 0.39 c€/kWh in France and 0.67 c€/kWh in Great Britain. Together with the Italian one, those estimates do not exceed €0.01[19]. A closer look at the

[17] They bear respectively 56%, 27% and 10% of the total obligation, altogether 48 TWh. A basic rule of thumb has been used to derive from these results the final values for the national objective of 54 TWh.

[18] We thank two of the reviewers for this suggestion.

[19] Or approximately $0.013 per kWh saved, to be compared with recent estimates of DSM programs: 0.034 $/kWh in dollar 2002 according to Gilligham et al. (2006); 0.06 $/kWh in dollar 2006 according to Arimura et al. (2009). Regarding the underlying tasks, the emphasis has been progressively shifted from information and loan programs to rebates (Nadel and Geller, 1996).

cost structure shows that obliged parties' burden is essentially made up of direct costs in Great Britain (85%), whereas the development of energy efficiency allegations in commercial offers has borne sizeable indirect costs in France (64%). The substantial difference between unitary direct costs (0.14 c€/kWh versus 0.57 c€/kWh) suggests that British suppliers have developed more costly strategies towards customers, i.e. more and/or larger rebates than in France, where energy suppliers seem to focus more on providing information.

		Great Britain 2005-08	**France 2006-09**	**Italy 2005-08**
Energy savings to target	**TWh**	**192**	**54**	**193**
Obliged parties direct cost	M€	1,085	74	-
Obliged parties indirect cost	M€	195	136	-
Total cost to obliged parties	**M€**	**1,280**	**210**	**216**
Unitary direct costs	c€ spent per kWh saved	0.57	0.14	-
Unitary indirect costs	c€ spent per kWh saved	0.10	0.25	-
Unitary total cost	**c€ spent per kWh saved**	**0.67**	**0.39**	**0.11**

Table 1. Comparison of the costs borne by obliged parties

These national aggregate results should not hide cost heterogeneity among obliged parties within countries. In Great Britain, it can be deducted from the transaction costs quantification of Mundaca (2007) that cost differences do not exceed 5% of the weighted average among all obliged electricity and natural gas suppliers. In France, there is a huge discrepancy between close unitary costs for electricity and gas suppliers on the one hand, and roughly double values for fuel oil retailers on the other. This can be explained by the observation that fuel oil retailers are more willing to provide rebates than other dominant suppliers in France. This will be further analysed in Section 6.1.

4. Balancing costs and benefits

Accounting for the costs borne by other parties allows estimating the cost of the "negawatt-hour" (Joskow and Marron, 1992; Gillingham *et al.*, 2006). Subsequently, energy and environmental benefits must be weighted against costs to complete a fully-fledged social efficiency assessment of white certificate schemes.

4.1 Contributions of other parties to total costs[20]

Once the contribution of obliged parties to the cost of energy efficiency improvements has been delimited, the remaining part is supposed to be borne by customers. It happens that some other contributors may often be involved. Throughout their action, especially when implementing measures towards low-income households, British suppliers have worked closely with social housing providers and managing agents. Those actors bore on the whole €151 million (Lees, 2008). In France, the pervasive overlap with the tax credit scheme makes the Government (and ultimately tax-payers) a significant contributor. Tax credits have represented on average 34% of capital costs of implemented measures and on the whole €1,305 million, as calculated in the Annex (Table A4). Net from other parties' direct contributions, the costs finally paid by customers amount to €325 million in Great Britain and €504 million in France.

		Great Britain 2005-08	France 2006-09
Obliged party total cost	M€	1,280	210
Customer direct cost	M€	325	504
Other party direct cost	M€	153	1,305
TOTAL COSTS	**M€**	**1,758**	**2,019**

Table 2. Comparison of total costs

Costs borne by public authorities for administering the scheme may also be a matter of concern. Lees (2008) estimates that costs incurred by the British administrator (Ofgem) is kept under 0.1% of energy supplier costs and those incurred by the regulator (Defra) are even lower. Administrative costs may be similarly negligible in the French and Italian schemes.

Total costs of the British and French schemes are summarized in Table 2. Similar ratios of direct costs over total costs in France (93%) and in Great Britain (89%) indicate that costs come essentially from energy efficiency improvements. In Great Britain, the share of total costs incurred by obliged parties and customers are 73% and 18%, respectively. Conversely in France, obliged parties bear only 10% of total costs and the scheme is primarily financed by end-use consumers, partly as measure beneficiaries and for most of the part as tax-

[20] Data is not available to perform such an evaluation for the Italian scheme. Note that regarding the operating mode that has prevailed up to now in the residential sector, namely the nearly free distribution of CFLs and water economizers, the cost to consumer might be close to zero. Note also that regulated distributors are granted €100 for every ton oil equivalent they save to recover the cost of the scheme. This is ultimately paid by tax-payers as a contribution to the energy tariff. It can be considered as a transfer within the scheme and hence should not be counted. Lastly, other costs should include, among others, the contribution of public authorities to the investment cost on measures realised on their premises, like public lighting.

payers. This huge gap raises important equity issues. It again reflects the fact that in Great Britain, energy suppliers contribute more directly to investment costs through large rebates compared to France, where this role is fulfilled by the tax credit scheme. For comparison, consumer costs are around 60% to 70% of costs under utilities' DSM programs (Nadel and Geller, 1996).

4.2 Social benefits

Benefits of the scheme accrue primarily to private customers from the reduction of their energy operating expenditures. Expressed in present monetary terms, for a constant average energy price of €0.08/kWh, the effective energy savings alleviate the French energy bill by €4,320 million. In Great Britain, Lees (2008, Table A5.3) reports present values of €6,720 million to electricity consumers, €5,640 million to gas consumers and €658 million to fuel consumers, thus on the whole €13,020 million. In Italy**,** Pavan (2008, Figure 3) figures out that avoided energy costs for consumers are around €600/toe for electricity and €750/toe for gas. This yields €7,980 million and €8,925 million of electricity and gas savings, for a total amount of €16,905 million.

From a social standpoint, the avoided CO_2 emissions represent an environmental benefit. Contrarily to energy, CO_2 is removed definitively once saved, so emission cuts are generally undiscounted (Lees, 2008). Their quantification will depend upon national mixes in electricity generation and the repartition of the scheme results by fuel type. This requires specific assumptions for France where fuel breakdowns are not disclosed by public authorities. Moreover, base electricity load is dominated by nuclear power and peak load is mainly supplied by fossil fuels. Therefore, estimates of carbon savings might differ whether one considers the *average* or *marginal* carbon content of electricity. Under these extreme assumptions, carbon dioxide savings are 17.1 $MtCO_2$ and 22.9 $MtCO_2$, with 20.0 $MtCO_2$ as a central value. Based on assumptions from other works, white certificate schemes have saved 72.6 $MtCO_2$ in Great Britain and 63.6 $MtCO_2$ in Italy.

The monetary valuation of carbon dioxide savings reflect national assumptions about the social value of carbon, which in turn reflect the carbon content of the energy supply system. In Great Britain and France, public authorities have defined temporal profiles of carbon abatement costs that will need to be incurred to meet national emissions reduction targets. Based on these pre-defined values, white certificate schemes yield environmental benefits of €7,686 million in Great Britain and €921 million in France (all assumptions are reported in the Annex, Table A1). Hence, the high fossil fuel content of the British electricity magnifies the gap already existing with France regarding private benefits. In Italy, in the absence of an official value of carbon, one default solution is to consider that carbon savings can be traded on the EU-ETS. Accordingly, and assuming a constant average market price of 20 €/tCO_2, the Italian scheme yields 1,290 million. To ease the comparison, CO_2 savings valuated at the same European price are also provided for Great Britain and France in Table 3.

		Great Britain 2005-08	France 2006-09	Italy 2005-08
End-use energy savings	TWh	192	54	193
Monetary value of energy savings	**M€**	**13,020**	**4,320**	**16,905**
CO_2 savings	$MtCO_2$	72.6	20.0	64.5
Monetary value of CO_2 savings, at European market price	M€	1,452	400	1,290
Monetary value of CO_2 savings, at national social value	**M€**	**7,686**	**921**	**-**
TOTAL BENEFITS, at CO_2 European market price	M€	14,472	4,720	17,935
TOTAL BENEFITS, at CO_2 national social value	**M€**	**20,706**	**5,241**	**-**

Table 3. Comparison of total benefits

Note that the alleviation of fuel poverty in the British scheme also provides social benefit. Yet this benefit is intangible in practice, and cannot be readily taken into account. Likewise, social benefits in terms of employment in the energy efficiency industry require a specific evaluation. Lastly, private benefits might accrue to certain obliged parties from market share gains at the expense of less skilled ones. They can be considered as transfers between energy companies, and as such they do not modify the final cost-benefit balance.

4.3 A social efficiency assessment

Putting total costs against effective energy savings allows estimating the cost-effectiveness of the scheme, otherwise known as the *negawatt-hour cost* (Joskow and Marron, 1992; Nadel and Geller, 1996; Gillingham *et al.*, 2006[21]). The comparison to the *kilowatt-hour cost* establishes the social desirability of the scheme. Table 4 exhibits a cost-effectiveness estimate for Great Britain that is far below energy prices[22]: 0.91 c€ per kWh saved, against an electricity price of 13.94 c€/kWh and a gas price of 3.7 c€/kWh. In France, the difference is much more tenuous, although still favourable to conservation: 3.74c€ per kWh saved, against 9.4 c€/kWh electricity price and 4.4 c€/kWh gas price. Overall, it is more profitable to save energy than to produce it, which is an *ex post* justification of the implementation of white certificate schemes from a social perspective. It remains that the policy must prove its efficiency, i.e. its ability to generate benefits that exceed costs. The French and British schemes (and very likely the Italian one) have undoubtedly gathered net social benefits.

[21] These authors review estimates ranging from $0.008/kWh to $0.229/kWh (in dollar 2002) for DSM programs.

[22] The Eurostat 2008 benchmark values are used, in line with Bertoldi *et al.* (2010).

They pay for themselves, whether environmental benefits from carbon dioxide savings are taken into account or not, and cost-efficiency estimates show very attractive paybacks: every euro spent returns €7.41 in Great Britain and €2.14 in France, excluding CO_2 savings (Table 4). Overall, white certificate schemes can thus be considered both cost-effective and socially efficient.

Explanations for the marked difference between French and British outcomes lie essentially in technological considerations. A long learning process, started with EESoP, has enabled British suppliers to identify CWI as a highly cost-effective potential and to develop economies of scale[23]. In contrast, French historic suppliers have thus far focused on heating system (heat pumps and condensing boilers), that are directly related to their commercial core business: such devices being essential to convert the energy they sale into a heating service, they have closer and more ancient relationships with heating system installers than with insulation installers. These measures happen to be costlier than in Great Britain because of a more recent market penetration. For instance, the average price of a condensing boiler reaches €2,200 in Great Britain (Lees, 2008) but up to €8,600 in France (OPEN, 2009). Lastly, theoretical lifetimes of insulation measures are typically 35-40 years, whereas they are only 15-20 years for heating systems. As a result, the British mix dominated by inexpensive and long-lasting insulation measures show better properties, in terms of both cost-effectiveness and cost-efficiency, than the French one dominated by expensive and short-lasting heating system replacement.

[23] It is noteworthy that the related cost decrease is apparently countervailed by the progressive shift towards costlier potentials. Indeed, cost-effectiveness estimates of the savings were 1.3 p/kWh for electricity and 0.5 p/kWh for gas during EEC1 and 2.1 p/kWh for electricity and 0.6 p/kWh for gas during EEC2 (Lees, 2005, 2008). Early evidence from the CERT scheme shows much higher cost-effectiveness estimates.

		Great Britain 2005-08	France 2006-09
End-use energy savings	**TWh**	**192**	**54**
Program costs	**M€**	**1,758**	**2,019**
Benefits, excluding CO_2 savings	M€	7,686	4,320
Benefits, including CO_2 savings	**M€**	**20,706**	**5,241**
Social cost-effectiveness	**c€ spent per kWh saved**	**0.91**	**3.74**
Net social benefits, excluding CO_2 savings	M€	11,262	2,301
Net social benefits, including CO_2 savings	**M€**	**18,948**	**3,222**
Cost-efficiency, excluding CO_2 savings	€ gained per € spent	7.41	2.14
Cost-efficiency, including CO_2 savings	**€ gained per € spent**	**11.78**	**2.60**

Table 4. Consolidated costs and benefits and social efficiency analysis

5. Interpreting costs: lessons about obliged parties' strategy

Prior to any *ex post* evaluation, the novelty of white certificate schemes makes them hard to characterize in theoretical terms. Since they promote performance rather than means, no specific delivery route is mandated and there are as many possible strategies as there are obliged parties. Moreover, within a *baseline and credit* framework, the innovative market component has aroused the enthusiasm of stakeholders but casted shadow over the importance of the elementary obligation component. To date, standard microeconomics has tended[24] to favour a stylized representation of white certificate schemes, generally portrayed as a hybrid combination of a subsidy for energy efficient goods with an end-use energy tax allowing cost recovery. This representation implicitly emphasizes transactions between obliged parties and related energy efficiency business, rather than trade among obliged parties.

[24] Albeit growing as schemes scale up, the theoretical literature on white certificate schemes is still scarce. Different approaches have been investigated, namely standard microeconomics (Bye and Bruvoll, 2008; Giraudet and Quirion, 2008; Oikonomou *et al.*, 2008; Peerels, 2008; Sorrell *et al.*, 2009), bottom-up modelling (Farinelli *et al.*, 2005; Oikonomou *et al.*, 2007; Peerels, 2008; Mundaca, 2008) and transaction cost approaches (Langniss and Praetorius, 2006; Mundaca, 2007).

The present section confronts these *ex ante* theoretical statements with the outcomes highlighted by the *ex post* evaluation that precedes. In particular, it investigates how the nature and amount of costs borne by obliged agents influence their effective compliance strategy compared to the theoretical one, on both the upstream side of the energy efficiency industry and the downstream side of end-use consumers. The following issues are addressed: *What is the extent of cost heterogeneity, which is a necessary condition for trading? How does the cost repartition affect the hybrid stylized representation?*

5.1 Cost heterogeneity and trade implications

The rationale for integrating market mechanisms in white certificate schemes is to equalize obliged parties' marginal costs and thus lower the total cost of the scheme. That is, a necessary condition for the market to be active and generate savings is for private costs to be heterogeneous. Applying the general framework provided by Newell and Stavins (2003) to white certificate schemes, cost heterogeneity might originate from (i) the heterogeneity in the efforts to be made by obliged parties (i.e. the difference between their individual obligation and their energy saving potential) and (ii) the heterogeneity in their energy saving cost functions. Regarding the first source, obligations in France and Great Britain are distributed among energy suppliers according to their market share in the residential sector. This is a fair criterion regarding competitiveness, but not necessarily reflecting the potential for energy savings really achievable by each participant. Regarding the second source, from the perspective of supporting the diffusion of goods that they do not produce, energy suppliers' cost function depends directly on their access to other energy efficiency businesses. It has been acknowledged that on dominating insulation measures in Great Britain, a competitive bidding process for dealing with subcontractors led to very similar measure costs to energy suppliers (Mundaca, 2007; Mundaca *et al.*,2008). This is likely to apply to other measures, in Great Britain as well as in France. Indeed, the second source is insignificant and the overall cost heterogeneity comes primarily from differences in individual targets, i.e. in market shares. Those are homogenous in Great Britain, where the market shares of the six obliged energy suppliers range from 11% to 32% (Lees, 2008, p.21), but heterogeneous in France, where EDF and GDF SUEZ bear 83% of the obligation while 2,500 medium or small energy companies bear the remaining part.

As a result, Section 4.3 has shown that estimated costs are quite homogenous in Great Britain. In France, the costs of the two dominant suppliers appeared very close, but the average cost for fuel oil retailers was more than twice higher. Against these estimations, a very low trade activity can be observed in both countries. White certificates exchanges happen to be negligible in Great Britain and cover only 4% of certified energy savings in France. However, one major energy supplier has acknowledged having tested market transactions in order to get a benchmark for his private costs. In this respect, note that the average cost to energy suppliers calculated in Section 5.1 (0.39 c€ per kWh saved) is close to the market average price (0.32 c€ per kWh saved).

Overall, in a context of low cost heterogeneity, the potential cost savings from trade (or opportunity cost of non-trading) are limited and offset by some costs of trading. In their extensive analysis of the market activity, Mundaca *et al.* (2008) refer to 'commercial benefits of non-trading' to introduce the risk of providing information to competitors when trading. Note also that French fuel oil retailers prefer to provide large rebates and thus bear higher costs than other suppliers to maintain their business, instead of buying white certificates. As a result, such costs of trading create a preference of obliged parties towards 'autarky', a phenomenon that has been observed in U.S. pollution cap and trade programs (Burtraw, 1996).

Lastly, preliminary lessons can be drawn from the incomplete analysis of the Italian scheme. Contrarily to other schemes, it shows a high level of market activity, since 79% of the white certificates issued have been traded on *spot* and *over-the-counter* markets (Pavan, 2008; Oikonomou *et al.*, 2009). However, this cannot be considered as a horizontal equalisation of obliged parties' marginal costs, since most of the transactions involved obliged energy distributors on the demand side and non-obliged energy service providers[25] on the supply side. Whereas obliged energy distributors can hardly promote energy savings to end-users that are not their customers, energy service providers can fill this gap by implementing energy efficiency measures and sell the related white certificates to energy distributors. Cost heterogeneity among energy distributors is likely to be very low, as regards their ability to subcontract with energy service providers. However, the unequal access to end-users between energy distributors and service providers can be interpreted as cost heterogeneity, favouring a vertical form of trade among agents that operate at different levels of the value chain (Radov *et al.*, 2006).

5.2 Nature of costs and validity of the hybrid mechanism

Let us examine how the hybrid subsidy-tax instrument mechanism established by microeconomic models in partial equilibrium conforms to reality. The magnitude of the subsidy component can be evaluated as the share of obliged parties' direct costs in total direct costs[26]. In Great Britain, energy suppliers' direct costs reach 70% of total direct costs, which confirms an intensive use of rebates. In France, aggregate energy suppliers' direct costs are 4% of total direct costs, but the picture is much contrasted between electricity and gas segments on the one hand, the fuel oil segment on the other. The former provide inexpensive services like information, diagnosis and advice, whereas the latter are more willing to grant subsidies.

[25] Energy service providers are subsidiaries of obliged distributors for 43% of these transactions (Pavan, 2008; Eyre *et al.*, 2009).

[26] Note that this is supplemented by an observation of obliged parties' advertising material, to ensure that large (respectively small) shares of total direct costs correspond effectively to commercial offers essentially based on subsidies (respectively on other energy services).

In parallel to the subsidy component, the tax component should be evaluated through retail energy prices. Their settlement depends upon the regulations prevailing in each country. In Great Britain, energy markets are competitive and energy prices are set freely. There is currently no way to decompose energy suppliers' margin and ascertain whether they fully pass through the compliance cost[27] to energy prices. Nevertheless, it is assumed as such by the British Government. Lees (2008) estimates that the expenditures by the energy suppliers represent on average 9.7€ per customer per year, equivalent to 1-2% of the average annual fuel bill. In France, dominant electricity and gas markets are less competitive and the Regulator has so far prohibited cost pass-through in these markets. Conversely on the fuel oil segment, output prices are set freely. As in Great Britain, however, the level of cost pass-through is unobservable, all the more blurred by the price fluctuations that followed the 2008 oil shock.

Although it cannot be asserted that the burden of the scheme is effectively passed-through by obliged parties to their output price, there is a sound correlation between permissive cost recovery rules and energy efficiency subsidisation in Great Britain and on the fuel oil segment in France. Where costs cannot be recovered, as on other segments in France, energy suppliers manage to develop less costly strategies. The theoretical hybrid mechanism is thus valid, but subject to regulatory considerations. In Italy, even in the absence of an in-depth cost analysis, it is known that energy distributors are regulated monopolies and the price of the distribution service includes the expenditures generated by the obligation, as a standard contribution of €100 per ton oil equivalent (toe) saved[28] (Pavan, 2008).

In addition to this mechanism, some other factors can be invoked to explain obliged parties' strategies towards end-use consumers. First, in France the tax credit scheme is a ready form of subsidy that obliged suppliers have just to advertise for. Yet this did not prevent fuel oil retailers to provide larger subsidies than other suppliers for the same type of measures (especially boiler replacement). In addition to their regulatory situation favouring the use of rebates, they actually need to keep incentives high to countervail the marked decline of their business with growing environmental concerns[29]. Second, the high competitiveness of energy markets in Great Britain provides higher incentives to differentiate through aggressive commercial offers, with a more intense use of rebates.

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[27] The compliance cost is supposed to equal the direct and indirect costs incurred by obliged parties, plus the opportunity cost of forgone energy sales.

[28] This has been changed in 2009 and the level of cost recovery now depends on energy sale price variation. This new regulation yielded an average 2009 cost recovery rate of €88.92 per toe saved (Bertoldi *et al.*, 2009).

[29] Interestingly, although not obliged at the beginning of the consultation process, fuel oil retailers saw an opportunity to make their business evolve and asked for participating to the scheme.

6. Conclusion

This paper was an attempt to cope with the low availability of data to estimate the costs and benefits of white certificate schemes, in order to assess to what extent they are cost-effective and economically efficient, i.e. minimizing costs to target and maximizing net benefits. Subsequently, some general insights about the conceptualization of the instrument have been derived from the analysis of the differences in national realisations.

From a methodological point of view, assessing the effectiveness of white certificates is eased by the use of standardized calculation. Note however that these are *ex ante* data, and its reliability should be reinforced by *ex post* controls (which has occurred in Great Britain and Italy, but not yet in France). Assessing costs that are not disclosed is a much more difficult task. It could be eased by the market price, which turns out to be meaningless for several reasons. The evaluator is forced to make assumptions that obliged parties are reluctant to discuss, by anticipating changes in target sizes that their indications could imply. Overall, the regulatory requirements of white certificate schemes provide more transparency about energy savings than DSM programs, but less transparency about costs. The way costs and benefits are subsequently interpreted raises further methodological issues. Cost-benefit analysis is of partial equilibrium nature and makes no case for macroeconomic retroactions (Goulder and Parry, 2008). Moreover, it is not a welfare assessment and fails short to capture adequately the benefits of the scheme (Gillingham *et al.*, 2006; Braithwait and Caves, 1994). Perhaps more importantly, cost-effectiveness and economic efficiency are essentially static statements, that is to say, holding for the given stages of the scheme. They abstract from powerful organisational and technological dynamics that, along with appropriate regulatory changes, could modify the cost-benefit structure in the long-run. This calls for a broader dynamic efficiency evaluation, factoring market transformation issues and organisational arrangements between stakeholders.

Despite these methodological limitations, this analysis confirms the early conclusion of Mundaca and Neij (2009) that white certificate schemes are a cost-effective and economically efficient policy instrument for energy efficiency. "Negawatt-hour" costs compare favourably to kilowatt-hour costs and white certificate schemes pay for themselves. This is even magnified further when environmental benefits are accounted for. However, this general result is contrasted among countries, notably with a huge efficiency discrepancy between the British scheme and its French counterpart. Discrepancies in total costs are mainly rooted in technological differences that lead to uneven energy saving potentials. Discrepancies in benefits come from different energy supply systems, which impact the retail energy price and the carbon content of electricity. Put another way, the French household sector was probably more energy efficient at the beginning of the scheme, hence incremental energy savings are more expensive. Recent indications that the costs of CERT are rising disproportionately (Purchas, 2009) confirms that Great Britain is moving on to costlier potentials. The same applies for Italy, where energy distributors show increasing difficulty to reach rapidly growing targets (Russolillo, 2008).

From a theoretical point of view, empirical results only partially validate the stylized representation of white certificate schemes depicted in microeconomic models. A positive correlation between energy efficiency subsidisation and permissive cost recovery rules has been identified, as well as a possible link between cost heterogeneity and the level of trade. Provided the relatively low targets and short experience so far with white certificate schemes, the analysis fell short of extricating more salient drivers from a bunch of contingent, country-specific factors working in different directions. This calls for further evaluation and stresses the need for more data, especially about the Italian scheme. Given its specific architecture and outcomes, a more systematic comparison of the three schemes should allow more robust interpretations.

Lastly, from a policy-making point of view, more attention should be paid to the distributive impacts of white certificate schemes across end-use consumers. With respect to the stylized representation, equity concerns arise if energy efficiency measures benefit to a reduced set of customers while being funded by all end-use consumers (Sorrell *et al.*, 2009). Such a situation apparently occurs in Great Britain, where all end-users probably face a uniform energy price increase. It also applies indirectly to France, where the costs of the scheme, although not passed-through to energy prices, are mostly borne as tax credits by taxpayers. This crucial problem is partially solved in Great Britain by an obligation to realise 50% of energy savings to low-income households. The rationale comes from the idea that energy efficient equipment correspond to high-end products that low-income households can barely afford, contrarily to the situation prevailing in transportation. This makes low-income households a deep and highly cost-effective potential for energy savings, hence justifying targeted support. In other words, focusing measures on low-income households is a way to raise the economic efficiency of the scheme while reducing adverse distributive impacts. Lees (2008, p.95) finds cost-efficiency estimates for measures targeted to low-income households that are twice higher than estimates for all householders. This should be considered for implementation in other schemes.

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Annex

	Great Britain	Italy	France
Average measures lifetime	34 years (Lees, personal communication) [4% discounted = 19.1]	8 years (own estimation) [4% discounted factor=7.0]	20 years (own estimation) [4% discounted = 14.1]
Fuel shares of energy savings	24% for electricity, 70% for gas and 6% for non gas fossil (Lees, 2008, Table 4.1)	52% for electricity, 48% for gas (see respective targets, Annex A2)	23% for electricity, 56% for gas and 21% for fuel oil (own estimation)
Social value of carbon used to calculate environmental benefits	Central value set by DECC (2010, Table 1), for policies affecting non-ETS sectors: 52 £/tCO_2 in 2010, 60 £/tCO_2 in 2020, 70 £/tCO_2 in 2030.	20€/tCO_2 (own assumption: in the absence of official value)	Official value set by Quinet et al. (2008): 32€/tCO_2 in 2010, 56€/tCO_2 in 2020 and 100€/tCO_2 in 2030.
Carbon dioxide content of energy	As of Lees (2008, Table A5.6): average of 378gCO_2/kWh	As of Eyre *et al.* (2009, Table 2): average of 330 gCO_2/kWh	For electric heating, the *average* value is 225 gCO_2/kWh (ADEME and EDF, 2005; ADEME, 2008b) and the *marginal* value is 550 gCO_2/kWh (ADEME and RTE, 2007). An intermediary value of 388 gCO_2/kWh is used. Natural gas and fuel oil values are 206 and 271 gCO_2/kWh, respectively (ADEME, 2008a).
Other common assumptions	• Discount rate=4% • €/£ exchange rate=1.4 (best guess of the average market exchange rate over the April 2005-March 2008 period) • kWh/toe=11,630		

Table A1. Numerical values and references of the main assumptions

		Electricity	Gas	TOTAL
2005 primary energy target	Mtoe	0.1	0.1	0.2
2006 primary energy target	Mtoe	0.2	0.2	0.4
2007 primary energy target	Mtoe	0.4	0.4	0.8
2008 primary energy target	Mtoe	1.2	1	2.2
2005-2008 primary energy target	Mtoe	1.9	1.7	3.6
2005-2008 lifetime primary energy target	Mtoe	13.3	11.9	25.2
2005-2008 lifetime end-use energy target	**TWh**	**102**	**91**	**193**

Table A2. Energy savings expressed in normalized units over the 2005-08 period in Italy

			Annual cost to companies covering 48 TWh				Total 3-year period cost	
			Company A	Company B	Company C	TOTAL	To 48 TWh	To target (54 TWh)
ANNUAL DIRECT COST		Advice	0.00	0.00	0.00	0	0	0
		Diagnosis	0.00	0.00	0.00	0	0	0
		Assistance for renovation	0.00	0.00	0.00	0	0	0
		Rebates and subsidies	3.00	4.73	10.88	19	56	62
		Soft loans	6.00	3.64	0.00	10	29	32
		Service revenue (1)	-5.80	-0.20	0.00	-6	-18	-20
ANNUAL INDIRECT COST	Variable costs	Call centers	9.90	0.00	0.00	10	30	33
		Technical advice	8.00	0.38	0.00	8	25	28
		Professional partnership	3.10	1.61	0.00	5	14	16
		Marketing	2.75	1.10	3.43	7	22	24
		Aministration	0.60	0.24		1	3	3
	Fixed costs	Training	0.00	0.00	0.00	0	0	0
		Commercial offer development	5.50	2.20	0.00	8	23	26
		Information networks	1.00	0.67	0.00	2	5	6

Total direct costs	**3**	**8**	**11**	**22**	**67**	**74**
Total indirect costs	**31**	**6**	**3**	**40**	**121**	**135**
including variable costs	*24*	*3*	*3*	*31*	*93*	*104*
including fixed costs	*7*	*3*	*0*	*9*	*28*	*31*
TOTAL COSTS	**34**	**14**	**14**	**63**	**188**	**210**

Share of total direct costs	**9%**	**57%**	**76%**	**35%**
Share of total indirect costs	**91%**	**43%**	**24%**	**65%**
including variable	*72%*	*23%*	*24%*	*50%*
including fixed	*19%*	*20%*	*0%*	*15%*
	100%	100%	100%	100%

This is the author's own estimation, based on:

(i) Information made available to the public by obliged parties

(ii) Bilateral interviews with obliged parties' representatives

(iii) Own assumptions about material costs and salaries

(1) Companies can get receipts from the sale of services such as diagnosis or advice

nota bene: where cost equals zero, the task is either not realised or realised at no additional cost (as reallocation of a pre-existing services)

Table A3. Estimate of obliged parties' costs in the French scheme

Measures mix as of July 1, 2009	%	TWh cumac*	kWh cumac per unit**	Unit	Unit numbers	Unitary cost (€)***	Gross cost (M€)	Additional cost rate***	Unitary additional cost	Net cost (M€)	Tax credit rate**	Tax credit cost (M€)
Individual condensing boiler	20.8	11.232	110 000		102 109	7 000	714.8	40%	2 000	**204.2**	30%	214.4
Individual low-temeprature boiler	11.5	6.21	55 000		112 909	6 000	677.5	20%	1 000	**112.9**	15%	101.6
Collective condensing boiler	7.5	4.05	100 000	dwelling	40 500	1 000	40.5	40%	286	**11.6**	0	0.0
Air-to-air heat pump	5.8	3.132	110 000		28 473	14 000	398.6	67%	5 617	**159.9**	50%	199.3
Roof and attic insulation	5.5	2.97	1 600	m²	1 856 250	30	55.7	100%	30	**55.7**	50%	27.8
Efficient glazing	4.3	2.322	4 400	window	527 727	800	422.2	100%	800	**422.2**	40%	168.9
Air-to-water heat pump	4.2	2.268	120 000		18 900	14 000	264.6	67%	5 617	**106.2**	50%	132.3
Collective low-temperature boiler	2.9	1.566	50 000	dwelling	31 320	800	25.1	20%	133	**4.2**	0%	0.0
Independant wood furnace	2.6	1.404	50 000		28 080	3 500	98.3	100%	3 500	**98.3**	50%	49.1
Wall insulation	2.4	1.296	2 500	m²	518 400	120	62.2	100%	120	**62.2**	40%	24.9
Solar water heating (overseas)	2.2	1.188	25 200	dwelling	22 500	3 750	84.4	100%	3 750	**84.4**	50%	42.2
LBC (overseas)	1.9	1.026	460		2 230 435	6	13.4	100%	6	**13.4**	0%	0.0
Individual boiler control	1.3	0.702	22 000		31 909	120	3.8	100%	120	**3.8**	30%	1.1
Water-to-water heat pump	1	0.54	120 000		4 500	14 000	63.0	67%	5 617	**25.3**	50%	31.5
District heating	1.1	0.594	125 000	dwelling	4 752	500	2.4	100%	500	**2.4**	50%	1.2
Condensing boiler, commercial	1.2	0.648	800	m²	810 000	15	12.2	100%	15	**12.2**	0%	0.0
TOTAL	**76.2**	**41.148**					**2 938.5**			**1 378.7**		**994.4**

Aggregate values	TWh	Gross cost	Net cost	Tax credit cost
To restricted perimeter	41	2 938	1 379	994
To target	**54**	**3 856**	**1 809**	**1 305**
Average rates			47%	34%

Cumac — *stands for "cumulé actualisé" (accumulated and discounted)*

Gross cost — *Whole investissement cost for all measures*
Additional cost rate — *Cost differential with the reference situation (see section 4.1)*
Net cost — *Cost of effective energy efficiency improvements*

* DGEC data
** Average from DGEC data
*** Author's own assumptions
no * Deduced from primary data (*,**,***)

Table A4. Estimate of the total costs of energy efficiency improvement in the French scheme

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