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A METHOD FOR ALLOCATING RENEWABLE ENERGY SOURCE SUBSIDIES AMONG FINAL ENERGY CONSUMERS

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In a new context of growing need for renewable energy sources (RES), tariff design has become a critical component of energy system regulation. A methodology for allocating the cost of RES subsidies that ensures an optimal balance between compliance with the main regulatory principles of tariff design and each State's specific policy is of cardinal importance in the current context. This paper presents and discusses a novel methodology to allocate RES subsidy costs consisting in distributing them among final energy consumers, in proportion to their consumption, regardless of the type of final energy consumed (liquid fuels, gas, electricity or coal).

First, the different RES subsidies designs are categorized and a review of a good number of the RES burden sharing mechanisms implemented in the EU is presented. Then, the proposed methodology is developed on the basis of the basic regulatory principles underlying tariff design and the current regulatory context in force in the EU.

Finally, to illustrate its actual impact in a real case example, the proposed methodology is applied to the Spanish system, in which the burden of extra-costs incurred for RES amounts to a very large proportion of the overall energy system costs.

Keywords: Renewable energy sources, tariff design, RES support mechanisms.

1 INTRODUCTION

Conserving the natural environment and securing national energy supply are two challenges of utmost importance facing energy systems today. Renewable energy sources (RES) indisputably afford a promising solution to these issues, so there has been a growing worldwide trend to incentivise the use of these resources, both in the electricity and transportation sectors (REN21, 2007).

RES are not yet proven to be economically competitive on liberalised wholesale energy and transport markets, despite the substantial improvement attendant upon technological maturity and concomitantly lower investment costs. As a result, in the vast majority of systems around the world their use depends on the implementation of a subsidy policy that provides investors with additional support to guarantee a reasonable return on their investments. Although such subsidies are not always easy to monetise, their cost must ultimately be defrayed by end-users, and/or by taxpayers (e.g. through energy tariffs and/or the national budget).

To date, debate in the literature on RES development has focused on defining to what extent its penetration is desirable or acceptable and on determining the regulatory instruments able to most efficiently meet the RES targets in each particular context. Specifically, attention has centred on the efficiency and effectiveness of RES support schemes, i.e. on achieving these targets at the lowest cost (Menanteau et al., 2003), (ECComm, 2008A) and (CEER, 2008).

The methodology for allocating the costs of RES subsidies among end-users has been only scantly addressed, however. In other words, debate has been skewed toward the most suitable regulatory treatment and remuneration to be applied to any given RES technology, while the

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methodology to determine the portion of these costs that should be borne by each type of consumer or the national budget, has been largely neglected. That notwithstanding, a few references provide a useful discussion of how the costs incurred to integrate RES in electric power systems (e.g., the grid reinforcement and investment and operation costs to be regulated) should be distributed among RES producers or consumers through access tariffs (see Barth et al., 2008, and Auer et al., 2007). Since all costs are ultimately defrayed by somebody (e.g. consumers or taxpayers in the short or eventually in the long term) the objective of the present paper is to discuss the distribution of the quantifiable extra costs associated with RES.

Over the years, the latter discussion has been far less significant in light of the relatively low burden RES costs have placed on consumers' energy bills. But this is no longer the case. In a new context of growing need for renewables not only for the power and transport industries but for countries' economies as a whole, together with some governments' perennial concern about political sensitivity to increasing energy and fuel rates, especially for electric power, energy tariff design has become a critical component of RES and energy system regulation. The better grounded the methodology for allocating these costs, the smaller is the risk of public dissatisfaction and hence the larger the amount of total RES that can be deployed[1]. This is the case of the Spanish energy system, for instance, due to the rapid growth of the share of renewable electricity output in the country's generation mix (around 25% of installed capacity in 2008), along with the associated costs. As shown in the practical example described in this paper, in Spain the extra remuneration for RES installation accruing from the feed-in tariff in place (i.e. the premium on top of the market price) accounted alone for over 10 % of the total cost of electric power. And according to Spanish National Energy Commission (CNE) projections, this share may exceed 20 % in only a few years' time.

Consequently, a methodology for allocating the cost of RES subsidies that ensures an optimal balance between compliance with the main regulatory principles of tariff design and each State's specific strategic policy is of cardinal importance in the current context.

This paper describes the proposal put forward in early 2008 by Comillas Pontifical University's Institute for Research in Technology for the CNE in the context of the development of a new methodology for designing access tariffs for the Spanish electric power system. Two years later, the proposal is currently being intensively debated in the Spanish energy system, supported by some of the main renewable associations (ASIF et al., 2010) and electricity generators (CNE, 2010) and severely criticised by the oil industry (Mazarrasa, 2010).

Caveat

As stated in the Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (adopted by the Commission in April 2009) "energy efficiency and energy saving policies are some of the most effective methods by which Member States can increase the percentage share of energy from renewable sources".

[1] Particularly in the case of electricity tariffs, it is often the case that regulators have preferred as less transparent as possible, under the belief that this lack of information would lead to less public dissatisfaction. In the case this paper is dealing with, and particularly in the EU context in which regulators are compelled to improve the transparency of their energy tariff designs, the current allocation criteria is sufficiently known by energy system actors and the debate is already intense, so there is no better way to tackle the matter than trying to be as orthodox as possible.

Both objectives, increasing RES production share and increasing energy efficiency are clearly interrelated.

The discussion in this paper is limited to the methodology to allocate RES subsidies costs, but the analysis and methodology would be equally valid to allocate the costs of efficiency programmes, such as smart meters, low-consumption bulbs, double-glazed windows or CHP (which is a way to reduce energy consumption by increasing efficiency) among end-users. And moreover, the main strength of the proposal is that contrary to the solutions implemented to date, the allocation methodology developed precisely contributes to send the right price signals to all energy consumers, contributing to enhance energy efficiency.

Roadmap

The paper is organised as follows: the following section contains a brief review of the nature of RES subsidies and a survey of the approaches in place in the European Union to allocate such costs in 2008. In section 3, the two criteria that delimit the proposal, the basic theoretical regulatory principles of tariff design, and the EU energy regulatory context, are introduced. Section 3 outlines the proposal in detail, with a practical example, applying the methodology to the Spanish energy system to illustrate and discuss the problems that arise during implementation.

2 BACKGROUND: RES SUBSIDIES AND ALLOCATION CRITERIA

2.1 RES subsidies classification

RES subsidies, which constitute market intervention on the part of the regulator, are designed to increase RES production by either lowering production costs or consumer prices to under market rates, or requiring demand to purchase a certain volume of RES energy. Such subsidies may be direct or indirect (Kammen and Pacca, 2004).

Indirect subsidies

Indirect subsidies are not explicit payments or discounts, but rather institutional support tools. They include research and development funding, below-cost provision of infrastructure or services or positive discriminatory rules, such as regulations facilitating grid access for RES power. The Commission of the European Communities (2008C) establishes RES dispatch priority or deems that "Member States may require transmission system operators and distribution system operators to bear, in full or in part, the costs (...) of technical adaptations, such as grid connections and grid reinforcements". In many electric power systems, RES are exempted from paying for the costs of imbalances and ancillary services in general.

Direct subsidies

Direct subsidies are explicit and quantifiable payments, grants, rebates or favourable tax rates. The most popular types of RES subsidies are feed-in tariffs (FITs) and premiums. FITs adopt the form of a tariff established by the competent authority for per MWh produced, whereas premiums are paid to producers in addition to the electricity market price[2]. In the EU, according to a European Commission staff working document on support for electricity from renewable energy sources (Commission of the European Communities, 2008B), FITs and

[2] Therefore, strictly speaking, further to the above definition of subsidy, the value of the RES subsidy for feed-in tariffs would be the difference between the feed-in tariff price paid to a generator per MWh produced and the system marginal price, i.e. the premium or its equivalent value.

premiums are used in 18 Member States. In the US, the federal renewable electricity production tax credit (PTC) is a per-kilowatt-hour tax credit for electricity generated by qualified energy resources.

In that same context, Directive 2003/96/EC4 explicitly provides that Member States may apply total or partial exemptions from or reductions in tax on RES electricity. The Council of European Energy Regulators (2008) lists a few examples of direct RES subsidies: in Finland and Norway project-specific investment grants are available for RES; in Romania renewable electricity is exempt from excise taxes; also in Norway the publicly owned enterprise Enova SF finances the cost of RES-powered heating systems for households.

The institution of a mandatory share of RES-generated electric power, such as in the renewable energy portfolio standards in place in a good number of states of the United States (Lauber, 2004) or tradable green certificate (TGC) schemes are examples of quasi-direct subsidies (it is not always obvious that a sufficiently reliable market price exists). The Renewable Obligations Scheme in force in the UK, for instance, requires suppliers to source part of their output with eligible renewables, beginning at 6.7 % in 2005-06 and rising to 15.4 % by 2015-16 (CEER, 2008).

Although the methodology proposed in section 3 below is thought to be applicable to any type of quantifiable RES subsidy, the discussion focuses here on how to distribute the costs derived from RES support schemes in the EU context. The starting point for the discussion, the criteria applied by a number of EU Member States to allocate the costs deriving from these subsidies, is examined in the following section.

2.2 RES support schemes and cost allocation criteria

As defined by the Commission of the European Communities (2008A), RES support mechanisms are schemes “originating from a market intervention by a Member State, that help energy from renewable sources to find a market by reducing the cost of production of this energy, increasing the price at which it can be sold, or increasing, by means of a renewable energy obligation or otherwise, the volume of such energy purchased”.

The objective of this section is to briefly outline the distribution of the extra costs deriving from the four categories of RES support schemes in 2008, i.e., who defrayed these costs (electricity consumers, domestic consumers only or taxpayers) and according to what criteria (per capacity contracted [MW], per energy consumed [MWh], per service connection) in EU Member States.

RES support schemes can be divided into four main categories: tax incentives/grants, quotas (TGC), FITs and premiums and tendering processes. In the case of the first ones, since a tax incentive implies an income reduction for the national budget, the costs are ultimately defrayed by taxpayers.

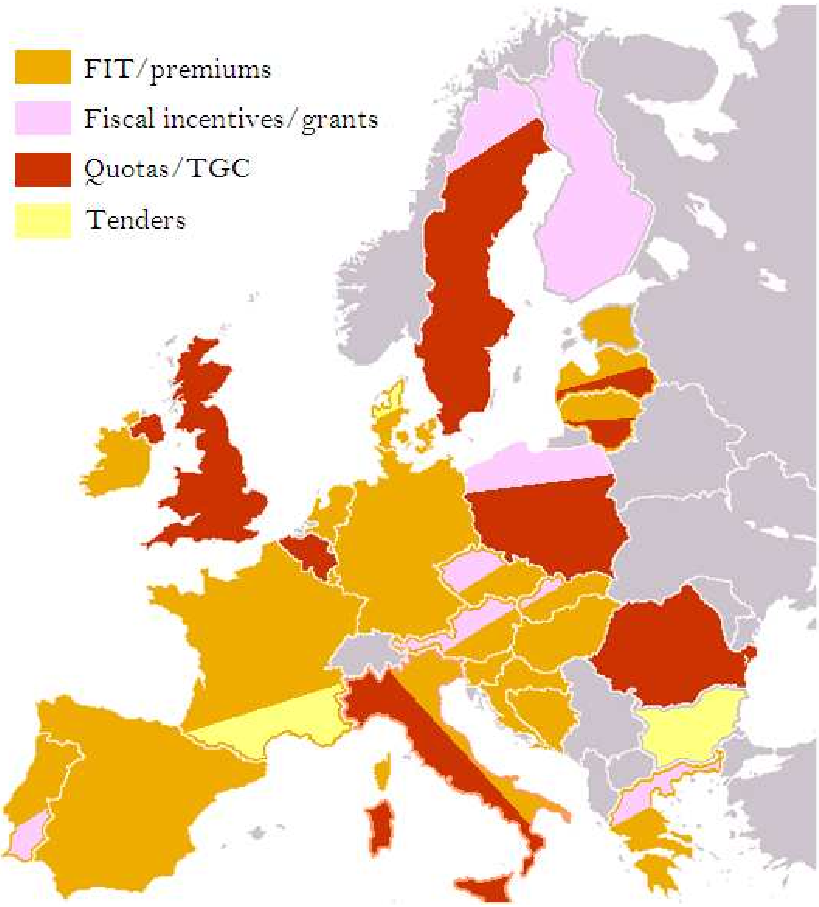

Figure 1. Support schemes in Europe (Commission of the European Communities, 2008A)

When a renewable energy obligation is instituted, the costs of the regulatory measure are borne by power consumers. However, since liberalised or regulated (last-resort) electricity retailers are the ones responsible for acquiring and paying for the opportunity cost of RES production, the allocation of these costs among their customers is left to their discretion.

Finally, FITs, premiums and tendering processes[3] are obvious examples of direct subsidies, since the resulting costs can be quantified straightforwardly. And in these cases the regulator must explicitly determine the methodology for allocating these costs.

A good number of the solutions implemented in the EU in 2008 are described below.

2.3 RES burden sharing in the EU

The objective is to summarise who (types of electricity consumers or taxpayers) pays the extra costs deriving from RES support schemes and under what criteria (e.g. per capacity contracted [MW], per energy consumed [MWh] or per consumer or service connection).

In Austria, the green power clearing and settlement agent OeMAG pays compensation in the form of renewable feed-in tariffs. Since 2007 these payments have been funded by flat-rate metering point charges billed to consumers (the amount of the charge depends on the voltage, with low voltage consumers bearing a larger burden) and the settlement price paid by electricity wholesalers for subsidised green power (E-Control, 2008).

[3] Roughly speaking, a tender process is nothing but a market mechanism to set the FIT or the premium price, see for example Bezerra et al. (2010).

In The Netherlands, the SDE scheme[4] (SenterNovem, 2007) is a feed-in premium subsidy scheme for RES investments whose costs are borne by the State. The budget available for SDE subsidies during 2008 was 1459 million euro.

In Denmark, according to Energinet.dk, the PSO tariff (Public Service Obligation) primarily covers subsidies for renewable energy and local CHP units as well as research funds and the administration of such funds. Grid companies pay a Public Service Obligation (PSO) tariff for the amount of electricity consumed in the area serviced (the charge in the West and East regions differs). For consumers, the settlement basis for the PSO tariff is the gross consumption (øre/kWh). A lower tariff is applied to consumption in excess of 100 GWh/year per service connection.

In Germany, the burden is shared equally and based on the energy component of the access tariff. Under certain conditions, the amount charged to energy-intensive industries and railway operators is capped (Klein et al., 2008).

In Italy, in addition to the institution of green certificates and fiscal incentives (a 10% reduction on the value-added tax for deliveries and services related to wind and solar investments), the costs of feed-in tariffs for solar photovoltaics are allocated to the access tariffs: an energy charge is set for low voltage consumers, while consumers with higher voltage connections pay an annual fixed charge per point of service, plus a decreasing and capped energy charge.

In France, besides a reduced VAT for RES installations, electricity tariffs include a so-called Contribution to the Public Electricity Service charge (*Contribution au service public de l'électricité*, CSPE), earmarked for RES support as well as other subsidies (to equalise island and continental electricity prices and to aid vulnerable consumers). The contribution is payable by all end users of electric power in proportion to the energy consumed, but is subject to a maximum value per service connection (CRE, 2008).

In Ireland, the Public Service Obligation (PSO) requires ESB Public Electricity Supply to purchase electricity from sustainable, renewable and indigenous sources. The PSO levy is charged to all electricity customers and is designed to recoup the additional costs incurred by ESB PES in meeting this obligation (CER, 2005). In 2006 the annual levy was a flat €9.68 per low voltage customer and a capacity charge of €5.26/kVA for medium and high voltage customers. In light of the steep decline in costs to be recovered via the PSO levy in 2007 (just 5 % of the previous year's figure) and the resulting very low levy, CER decided to set the levy to zero in that year (CER, 2006).

In Portugal, the Global System Use charge (*tarifa de Uso Global do Sistema*) was instituted to recover the System Operation costs as well as the overcosts associated with renewable generation and other energy policies (Apolinario et al., 2006). The price variable in this tariff is energy supplied (EUR/MWh) by time period (peak-time, partial peak-time, off peak-time and super off peak-time).

In the Czech Republic, in addition to an access tariff charge to cover the extra cost of renewable (RES) electricity and combined heat and power production, in 2008 an environmental tax was levied on electricity (CZK/MWh). The tax is paid by the electricity supplier to the Customs Administration as a lump sum for all customers, with the exception of tax-exempt renewable electricity and power consumed in energy-intensive processes and public transit.

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[4] SDE: Stimulering Duurzame Energieproductie (Incentive scheme for sustainable energy production).

In Estonia, the charge for defraying the costs of the RES-E purchase obligation was separated from grid charges in May 2007 and converted into the same rate per kWh for all types of consumers. In 2007, all consumers paid 2.18 EEK cents/kWh for this item, while in 2008 the charge was 3.03 EEK cents/kWh (Konkurentsiamet, 2008).

In Greece[5] and in Hungary, renewable cost-related energy charges (EUR/MWh) are included in the access tariffs (ENTSOE, 2008).

Finally, in Spain, the costs of RES direct subsidies are included in the grid access costs. As no tariff design methodology has been published, information on the distribution of these costs among different types of consumers is not available. The methodology proposed here is illustrated in the following section, taking Spain as an example.

3 GUIDING PRINCIPLES AND THE EU CONTEXT

Before describing the methodology for allocating the RES subsidy costs proposed in this paper, the two criteria by which it is governed should be introduced: the theoretical regulatory principles that must be borne in mind when designing tariffs, and the regulatory context in which the energy supply problem arises.

3.1 Regulatory principles underlying tariff design

The ultimate objective of any tariff design should be to strike a reasonable balance among the principles listed below (Kahn, 1988; Pérez-Arriaga, 2001; Berg, 1998).

- Financial viability of the firms. Tariffs must be cost-reflective. The recovery of all regulated costs plus a reasonable rate of return must be guaranteed to ensure that the energy industry is economically viable.
- Equity (fairness) and non-discrimination (Lévêque, 2003). Rates are regarded to be non-discriminatory if everyone is charged the same amount for using the same good or service, regardless of the purpose to which it is put and the identity of the user. A situation directly associated with discrimination that should not be allowed is the existence of cross-subsidies between tariffs[6]. Each user should pay his or her own costs, exclusively and completely. The tariff must lie in-between the marginal cost of the good or service and the cost of providing such good or service solely to the customer whose tariff is being defined.
- Economic efficiency. In particular, from the standpoint of allocative efficiency, the focus of this paper, one main criteria should be considered: marginal cost pricing, to ensure that tariffs send economic signals that encourage efficient operation and investment.

  Additionally, cost causality, whereby everyone assumes the part of the cost for which he/she is responsible, depending on the intensity of use of the good or service, is a complementary principle linking economic efficiency and non-discrimination.

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[5] Also, the new Law 3299/2004 provided grants covered by the national budget of up to 40% of the total RES investment.

[6] This does not mean that cross subsidization is never desirable, but rather that in case of considering the contrary, as commonly accepted in fundamental economic theory, the proper way to implement it would be resorting to fiscal measures (taxes) but not altering the right efficiency signals for consumers provided by the tariffs.

- Additivity. Tariffs must explicitly include every cost item, which should be recovered under a regulated and differentiated component. The resulting tariff should be the sum of all these items, with no inter-activity cross-subsidies.

These are not the only tariff principles, however. Others, including transparency, stability, simplicity, consistency with each country's specific regulatory process and objectivity (absence of arbitrary precepts), must also be considered.

It is not always easy or even possible to fully comply with all of these criteria at once, for principles more than often clash. Yet they must all be borne in mind to understand the reasoning behind certain design decisions and define the ultimate goal in the awareness of what must be forfeited in its achievement.

The objective pursued, as stated above, is to strike a reasonable balance among these fundamental principles. Since as stated they often clash, a decision has to be made in each particular case to prioritize some principles over others. This is why it is of utmost importance to analyze the particular regulatory and economic context for which the cost allocation methodology is proposed. Thus, next the main drivers of the EU context in relation with RES are introduced. Then, on this basis, it is discussed which in opinion of the author should be the principles that should be prioritized.

3.2 The Directive 2009/28/EC

The Directive 2009/28/EC establishes "mandatory national targets consistent with a 20 % share of energy from renewable sources and a 10 % share of energy from renewable sources in transport in Community energy consumption by 2020". This target is translated into individual targets for each Member State. Also, "each Member State shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10 % of the final consumption of energy in transport in that Member State".

Also, it is stated that "the development of energy from renewable sources should be closely linked to increased energy efficiency". Later, it is established that the Commission shall present "a review of the cost-efficiency of the measures to be implemented to achieve the target".

In the preface of the Directive it is also stated that "the control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012. Those factors also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas".

Three key conclusions can be drawn from the grounds for and objectives of the proposed methodology:

- The Directive set a common and equally binding target on all final energy consumers (coal, oil, gas and electricity).
- Energy and cost efficiency are key goals accompanying the targets.

- One of the essential reasons for implementing regulated incentives to support RES is not strictly associated with any energy industry objective[7].

With these facts in mind and the previously introduced tariff design principles, a methodology to distribute the extra costs incurred by national RES support schemes is discussed below.

4 METHODOLOGY TO ALLOCATE THE COST OF NATIONAL SCHEMES TO SUPPORT RES

It has been stated that when designing tariffs, there is not always a solution able to fully accomplish with all the regulatory principles mentioned. The one proposed here, which entails allocating the extra costs of RES promotion programmes among all manner of final energy consumers, not just electric power users, is aimed at complying with the main ones. First, the non-discrimination principle, in the context of the Directive target (binding for all final energy consumers) means that all final energy consumers should bear the extra costs of RES. Also, as Kahn (1988) upholds, the fundamental rules in tariff design are "one, that price to all buyers be equated with marginal costs and two, that total revenues cover total costs." The discussion that follows is built upon a stylized mathematical model which allows demonstrating that the allocation criteria proposed accomplishes with these two basic tariff design regulatory principles.

Allocative efficiency, as discussed in the foregoing and defined in BoKIR (2008), describes a situation where least cost production (production efficiency) has been established and price equals marginal cost. Consequently, the consumers' marginal utility purchasing the product equals the opportunity cost of supplying it. The resulting product mix and output levels yield maximum benefits, given the existing production technology and market agents' preferences.

Maximizing energy production efficiency entails minimizing production costs. In addition, under the Directive 2009/28/EC, each government can formulate its own strategy to meet the target, designing different mechanisms to provide extra funding for the RES regarded to be most suitable for the national interest as a whole. The binding target laid down in the proposal for a directive that requires each and every Member State to derive percentage of its energy from renewable sources can, then, be expressed as a linear constraint.

The model presented below, which allows deriving the expression of the right marginal price that should be passed through final energy consumers is based on some basic assumptions:

- Just to clarify notation and simplify the model formulation, the production cost functions considered in the model, i.e. the functions representing the total cost incurred when producing any of the final energy fuels (i.e. liquid fuels, electricity, gas, coal) from any of the primary fuels (e.g. the electricity generation cost), are assumed to be linear functions of the energy production.
- Instead of expressing the energy supply problem in a Member State as a production cost minimization, the problem is modelled as a minimization of end-users' payments. The intention is to allow for a better representation of the RES target problem defined by the Directive, which sets the constraint at the final energy consumption level. Since it is

[7] Two clearly distinguishable objectives justify the overcosts involved in these regulated incentives (premiums and tax incentives): social-economic development on the one hand (employment, economic growth, competitiveness and regional and rural development; see for example Moreno and Lopez, 2008) and sustainability on the other (reduction of GHG emissions and security of supply).

assumed that production cost functions are linear, payments minimization provides the same solution as production cost minimization, see Vázquez et al. (2002).

- The Directive target is expressed as a percentage of the final energy consumption, the problem differentiates between primary fuels (oil, gas, coal, uranium, wind, biomass, etc.) and final ones (liquid fuels, electricity, gas and coal), considering in the model formulation as well as in the final allocation proposal just these latter. To simplify the discussion, no interrelation between them is represented, i.e. implicitly final gas (the one consumed by end-users) and primary gas (the one consumed to generate final energy, for example the gas burned by CCGT to produce electricity) are distinguished and decoupled. Therefore, generators acquiring gas for producing electricity with gas turbines are not considered in the model as final energy consumers, in this the gas they acquire it is considered as a primary fuel. This is a relevant distinction, since what it is going to be proposed is to allocate part of the RES costs among gas or coal end-users. A CCGT or a coal generating unit are not end-users, so no burden should be applied to them. On the contrary, the optimal operation of the electric power system would be inefficiently affected, since they would internalize this new cost in their short-term bidding decisions.

- Since RES subsidies are not always quantifiable, the key requisite for the methodology proposal that follows is the computability of direct subsidies, so they can be readily managed and apportioned in the tariff design process[8].

4.1 Energy supply problem under the 20% RES constraint

In a first step, the problem just represents the overall binding target of a 20% share of RES in energy consumption, and not the 10% binding minimum target for energy from renewable sources in transport, which is discussed later. Thus, under these assumptions, the representation of the energy supply problem in a Member State is:

$$
\begin{aligned}
&\underset{E_f^{NRES},E^{RES}}{Min} \quad \sum_f E_f^{NRES} \cdot C_f + E^{RES} \cdot C_r, \quad f = 1,\ldots,F. \\
&s.t. \\
&\qquad E_f^{NRES} \le E_f \perp \mu_f, \quad \forall f \\
&\qquad \sum_f E_f^{NRES} + E^{RES} = \sum_f E_f \perp \varphi \\
&\qquad E^{RES} \ge 20\% \cdot \sum_f E_f \perp \zeta
\end{aligned}
\qquad \text{(Eq. 1)}
$$

Where:

E_f is the annual consumption of f, i.e., any of the forms of F final energy used in a Member State (such as liquid fuels, electricity, gas or coal). Such consumption can be expressed in toe[9].

[8] However, some of the so-called indirect subsidies might also be quantified in some manner, and thus be deemed to be direct subsidies. For instance, grid connection costs (as well as reinforcement costs, albeit less readily) or the cost of imbalances derived from wind production volatility could be somehow computed.

[9] toe: Tonnes of oil equivalent, defined by the IEA/OECD to be equal to 41.868 GJ or 11.630 MWh.

E_f^{NRES} is the annual energy production of one of the final fuels, f, from non-renewable primary fuels (such as oil, gas, coal, uranium).

C_f represents the cost incurred when producing an additional unit of final energy f, expressed in [EUR/toe]. This expression corresponds with the marginal cost function in each of the markets for final fuels (e.g. electricity or gas). As the production cost functions are assumed to be linear, these marginal costs are constant.

E^{RES} is the annual RES energy production (as defined in the Directive 2009/28/EC[10]) in a Member State.

C_r is the cost of producing an additional toe from the most efficient RES. Given that ideally long- and short-term system marginal costs are equal and assuming that the cost of RES is properly calculated to be the value of the feed-in tariff expressed in EUR/toe, to meet market demands, the next additional unit of capacity would have to be produced by the most efficient RES.

μ_f are the F dual variables of the constraints meaning that each of the F energy markets considered are final, and therefore the energy consumed in each market with non-renewable origin (i.e. from any of the primary fuels) cannot exceed the total demand in this market.

φ is the dual variable of the total final energy demand constraint.

ζ is the dual variable of the 20% share of RES constraint established by the Proposal of Directive.

The expression of Lagrangian function is:

$$\begin{aligned}\mathcal{L} = &\sum_f E_f^{NRES} \cdot C_f + E^{RES} \cdot C_r + \\ &+\sum_f \mu_f \cdot (E_f - E_f^{NRES}) + \varphi \cdot (\sum_f E_f - \sum_f E_f^{NRES} - E^{RES}) + \\ &+\zeta \cdot (20\% \cdot \sum_f E_f - E^{RES})\end{aligned} \qquad \text{(Eq. 2)}$$

Calculating the first order derivative with respect to the decision variables, the first order optimality conditions of the problem are:

$$\frac{\partial \mathcal{L}}{\partial E_f^{NRES}} = 0 = C_f - \mu_f - \varphi, \forall f \qquad \text{(Eq. 3)}$$

$$\frac{\partial \mathcal{L}}{\partial E^{RES}} = 0 = C_r - \varphi - \zeta \qquad \text{(Eq. 4)}$$

So,

[10] 'Energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.

$$\mu_f + \varphi = C_f, \forall f \quad \text{(Eq. 5)}$$

$$\zeta = C_r - \varphi \quad \text{(Eq. 6)}$$

Thus, the expression of the marginal cost of the objective function with respect to the annual consumption of any of the final fuels is:

$$\frac{\partial \mathcal{L}}{\partial E_f} = +\mu_f + \varphi + 20\% \cdot \zeta, \forall f \quad \text{(Eq. 7)}$$

Considering (Eq. 5) and (Eq. 6):

$$\frac{\partial \mathcal{L}}{\partial E_f} = C_f + 20\% \cdot (C_r - C_f + \mu_f), \forall f \quad \text{(Eq. 8)}$$

If the decision about in which energy market is most efficient to generate final energy from RES is optimized, (in principle) only one of the μ_f dual variables is zero, i. e. only in one case the constraint is not active.

So, let f_e be the final fuel for which the constraint is not active, i. e. $E_{f_e}^{NRES} < E_{f_e}$, so $\mu_{f_e} = 0$ (for example electricity, meaning that for instance the most efficient RES would be wind power generation). Then, the marginal cost price that should be transferred to final electricity consumers would be:

$$\frac{\partial \mathcal{L}}{\partial E_{f_e}} = C_{f_e} + 20\% \cdot (C_r - C_{f_e}) \quad \text{(Eq. 9)}$$

The right price to be passed through the final electricity consumers should be the electricity market marginal price plus 20% of the value of the RES premium, i. e. in the case of the example, the difference between the marginal cost of wind generation, the wind FIT, and the electricity market marginal price[11].

And also, if $\mu_{f_e} = 0$, then from (Eq. 5):

$$\varphi = C_{f_e} \quad \text{(Eq. 10)}$$

Therefore, for $f \neq f_e$:

$$\mu_f = C_r - C_{f_e} \quad \text{(Eq. 11)}$$

So, for the remaining final fuels, the marginal price signal would also be the sum of the market price plus 20% of the value of the RES premium:

[11] This 20% value should be the one to be applied once and ever since the binding target is achieved. In the transitory period towards this objective, although the constraint would be active, the right share to be applied to calculate tariff prices for each period (e.g. year) should be the RES share at this point in time.

$$\frac{\partial \mathcal{L}}{\partial E_f} = C_f + 20\% \cdot (C_r - C_{f_e}), \forall f \qquad \text{(Eq. 12)}$$

It can also be easily demonstrated that, if RES subsidies are implemented to fund only the most efficient RES (i. e. the one whose cost is C_r), this marginal cost pricing distribution criteria, besides leading to allocative efficiency, guarantees the whole production cost recovery.

Thus, under the hypothesis that a Member State just invests in the most cost efficient RES technology to fulfil the target, it has been shown that the proposed solution accomplishes with the two fundamental rules in tariff design previously mentioned in the words of Kahn (1988).

4.2 Allocation of the extra costs of subsidies for the RES less efficient in the short term

Nonetheless, RES subsidies are not just implemented to fund one single RES. And therefore the extra costs derived from these other subsidisation programs for alternative and less efficient (at least in the short term) would not be recovered by just applying the marginal pricing rule just discussed. For instance, in the Spanish system, in 2007 Royal Decree 661 established a FIT for solar photovoltaic installations of up to 470 EUR/MWh[12], while the payment for wind was capped at around 90 EUR/MWh (electricity market price plus premium).

Thus, since marginal cost pricing criteria does not allow recovering the costs driven by the support mechanisms for these other RES different from the most efficient one in a particular point in time, other criteria should be taken into consideration.

On the basis of the cost-causality principle, the first question to be addressed is whether these extra costs should be defrayed directly by final energy consumers or not. And if the decision is to for the first alternative, how these cost should be allocated into the different categories of energy consumers.

Distribution between common social interests and final energy consumers

The European Union has long recognised the need to further the use of renewable energy. Such wider usage would not only mitigate climate change by reducing GHG emissions, but would contribute to the development of a knowledge-based industry that would create jobs, foster economic growth, enhance competitiveness and spur regional and rural development.

Further to the cost causality principle mentioned above, the fact that these latter objectives involve national society as a whole could justify the inclusion of an item on the yearly budget to cover these extra cost that marginal pricing does not allow to fully recover.

While such an approach may be justified, its implementation, according to the EU regulations is not easily tenable (see discussion in next section about State aid rules) and also other reasons can be argued to uphold that transferring the full RES subsidy cost to consumers would be a better solution. A sound reason for not subsidising RES generation with taxes is that such a procedure would weaken the price signal perceived by energy consumers, which runs counter to the aim of reducing energy consumption and increasing energy efficiency.

[12] At the time of this writing, in 2008, the Spanish Government announced a reduction of this FIT for PV of more than a hundred euros.

Assuming the decision to invest in these alternative RES technologies is based on the expectation that promoting a (reasonable and controlled) deployment of these technologies in the short and medium term will result in an efficient solution in the very long term, it is possible to conclude that these subsidies are expected to reduce the cost for all sort of final energy consumers of fulfilling current (and potential more ambitious future) RES targets. Thus, again, since all the final energy consumers are expected to benefit from this regulated financing, these subsidy-driven costs should be allocated among all the end-users of the different energy fuels.

Conversely, an argument in favour of deriving some of the costs of RES subsidies to the national budget would be not to interfere with the competitiveness of the country's electricity-intensive industries. But as this objective clashes with the principle of reducing energy intensity, before covering part of the RES extra costs with the national budget, the extent to which energy prices jeopardize the competitiveness of each local industry should be carefully assessed. If the conclusion reached is that a number of them would be adversely impacted, the regulator can always resort to price discrimination in the access tariffs.

In a competitive environment, where short-term consumer behaviour must be distorted as little as possible and the most active customers maintained, it could make sense to use a proxy of the Ramsey allocation (Sheshinski, 1986) for this purpose, attributing less to the more elastic consumers. This approach often turns to be inconsistent with the government's objectives, see BoKIR (2008), and it is not always easy to implement, since for instance it is not easy to assess the actual elasticity of the different segments of consumers.

The case of the 10% binding minimum target for renewables in transport

The mandatory 10 % target for transport to be achieved by all Member States should therefore be defined as that share of final energy consumed in transport which is to be achieved from renewable sources as a whole, and not from biofuels alone. This distinction mainly has to do with the expected deployment of all kinds of electric vehicles (EV). However, since the development of this technology is expected to be still weak in the years to come (before 2020) and to simplify the discussion, in the following it is assumed that the transport target will be fulfilled resorting just to biofuels.

The way the 10% binding minimum target for biofuels is articulated in the Directive entails that the application of the marginal cost pricing principle would not lead to sharing the biofuels costs among all final energy consumers, regardless of the type of final energy involved, but just to the transport users.

Let us take the energy supply problem expressed in (Eq. 1), and let us add the corresponding constraint:

$$\begin{aligned}
&\underset{E_f^{NRES},E^{RES},E^{BF}}{Min} \quad \sum_f E_f^{NRES}\cdot C_f + E^{RES}\cdot C_r + E^{BF}\cdot C_{bf}, \quad f=1,\ldots,F. \\
&s.t. \\
&E_f^{NRES} \le E_f \perp \mu_f, \quad \forall f \\
&\sum_f E_f^{NRES} + E^{RES} + E^{BF} = \sum_f E_f \perp \psi \\
&E^{RES} + E^{BF} \ge 20\%\cdot\sum_f E_f \perp \zeta \\
&E^{BF} \ge 10\%\cdot E_{f_p} \perp \xi
\end{aligned} \qquad \text{(Eq. 13)}$$

Where:

E^{BF} is the annual biofuels production. In this case, E^{RES} is the energy production from RES except biofuels.

C_{bf} is the cost of producing an additional toe from biofuels.

E_{f_p} is the annual energy production of liquid fuel for transport, f_p, from non-renewable primary fuels.

ξ is the dual variable of the constraint meaning that at least 10% of the total liquid fuel consumption, E_{f_p}, have to be produced from biofuels.

The expression of Lagrangian function is:

$$\begin{aligned}\mathcal{L} = & \sum_f E_f^{NRES} \cdot C_f + E^{RES} \cdot C_r + E^{BF} \cdot C_{bf} + \\ & + \sum_f \mu_f \cdot (E_f - E_f^{NRES}) + \varphi \cdot (\sum_f E_f - \sum_f E_f^{NRES} - E^{RES} - E^{BF}) + \\ & + \zeta \cdot (20\% \cdot \sum_f E_f - E^{RES} - E^{BF}) + \xi \cdot (10\% \cdot E_{f_p} - E^{BF})\end{aligned} \qquad \text{(Eq. 14)}$$

Calculating the first order derivative with respect to the decision variables, the first order optimality conditions of the problem are:

$$\frac{\partial \mathcal{L}}{\partial E_f^{NRES}} = 0 = C_f - \mu_f - \varphi, \forall f \qquad \text{(Eq. 15)}$$

$$\frac{\partial \mathcal{L}}{\partial E^{RES}} = 0 = C_r - \varphi - \zeta \qquad \text{(Eq. 16)}$$

$$\frac{\partial \mathcal{L}}{\partial E^{BF}} = 0 = C_{bf} - \varphi - \zeta - \xi \qquad \text{(Eq. 17)}$$

Thus, the expressions of the marginal cost of the objective function with respect to the annual consumption of the different final fuels are:

$$\frac{\partial \mathcal{L}}{\partial E_f} = +\mu_f + \varphi + 20\% \cdot \zeta, \forall f \neq f_p \qquad \text{(Eq. 18)}$$

$$\frac{\partial \mathcal{L}}{\partial E_{f_p}} = +\mu_f + \varphi + 20\% \cdot \zeta + 10\% \cdot \xi \qquad \text{(Eq. 19)}$$

Now, two cases are considered:

- First, let f_e be the final fuel for which the constraint is not active, but in this case $f_e \neq f_p$, i.e. any final fuel except liquid fuels. Then, following the same procedure we get to the solution that the marginal cost price that should be transferred to end-users of any final fuel except liquid fuels would be:

$$\frac{\partial \mathcal{L}}{\partial E_f} = C_f + 20\% \cdot (C_r - C_{f_e}), \forall f \neq f_p \qquad \text{(Eq. 20)}$$

Under this assumption, the price for liquid fuels then would be:

$$\frac{\partial \mathcal{L}}{\partial E_{f_p}} = C_{f_p} + 20\% \cdot (C_r - C_{f_e}) + 10\% \cdot (C_{bf} - C_r) \qquad \text{(Eq. 21)}$$

As expected, since the 10% biofuels binding target only affects transport, marginal cost pricing entails that it would be up to liquid fuels consumers to defray the extra costs derived from this target.

- Conversely, if biofuels are the most efficient RES, then the 10% biofuels binding target constraint would not be active, and the right marginal price signal for all final fuel consumers would then be:

$$\frac{\partial \mathcal{L}}{\partial E_f} = C_f + 20\% \cdot (C_{bf} - C_{f_p}), \forall f \qquad \text{(Eq. 22)}$$

But again, it could be reasonable to apply the same reasoning followed above to decide the most adequate methodology to distribute the RES less efficient in the short term. This biofuels binding target can be understood in the same way as a regulatory decision to implement for example a FIT for solar photovoltaic installations. So the proposal could be to treat the potential extra cost driven by the biofuels binding target in the same way, i.e. to distribute them among all final energy consumers together with the rest.

Thus the conclusion and the corresponding proposal drawn after this discussion is the following: All energy consumers should pay the costs of renewable promotion programmes in proportion to their final energy consumption, regardless of the origin of renewable energy (such as biofuels or wind or solar energy). Based on the criteria previously discussed, or other which could be particular of a Member State, other alternatives could be conceived to allocate the extra costs derived from the support of the RES technologies that are not the most efficient ones at least in the short term, as for instance resorting to tax incentives or any other funding coming from the national budget.

Hence, the methodology for apportioning the costs of supporting renewable energy sources consists of estimating the final energy consumption of the various alternatives and then calculating the expected share in total final energy consumption. For fuels, the charge should be distributed in proportion to energy consumption, i.e. liquid fuel [€/litre], electricity [€/MWh], gas [€/MWh or €/Btu] and coal [€/ton].

4.3 Means to collect the from the different final energy consumers

Once the yearly amount to be distributed among all end-users is calculated, the best way to collect that sum from each of the four energy vectors (via levy or directly through an access tariff) must be established. That issue falls far from the central purpose of the present paper, since it requires a thorough legal analysis, so as to comply with the Community tax rules and the State aid rules. Thus, next the question is just outlined.

In principle, for electric power consumers, the proposal is to continue to charge this cost as part of the access-to-the-networks tariff, and in particular, the energy component of that tariff (for reasons of consistency with the general criterion that forms the backbone of the overall proposal, which is none other than to comply with the constraint laid down in the Directive, established in terms of energy only).

Nonetheless, the mechanism to allow for the collection of the remaining lots corresponding to end-users of the remaining fuels (liquid fuels, gas or coal) would entail levying an excise duty for specific purposes[13]. In principle, this tax could take the form of an environmental tax levy which eventually, the Energy Regulatory Authority could collect in order to directly devote it to defray the RES subsidy-driven costs[14].

However, this excise duty should be carefully designed and analysed, so as to comply with the Community tax rules and the State aid rules.

The Treaty on the Functioning of the European Union provides that State aid is, in principle, incompatible with the common market and requires Member States to inform the Commission in advance of any plan to grant State aid. The Vademecum published by the Directorate-General for Competition (European Communities, 2008) contains a summary of State aid legislation on "Aid for climate change and other environmental protection", including the thresholds triggering detailed assessment by the Commission and the RES eligible costs.

As it can be read in the Vademecum, 'the assessment of aid compatibility is essentially a balancing of the positive effects of aid (in terms of contributing to the achievement of a well-defined objective of common interest) and its negative effects (namely the resulting distortion of competition and trade)' In principle, the proposed methodology would clearly contribute to the achievement of a well-defined objective of common interest and it would not increase the distortion of competition and trade (the subsidies are already implemented, and the future trend is in most cases already defined in the Member States' plans, as for instance the Spanish Renewable Energy Plan (*Plan de Energías Renovables en España*) for 2005-2010 (MITyC and IDAE, 2005).

Besides, the proposed methodology, as it has been thoroughly demonstrated achieves two major objectives that are also mentioned in the guidelines, efficiency and equity. These objectives are guaranteed on the basis of the fulfilment of the main allocative efficiency principles, the marginal cost pricing and cost causality criteria.

4.4 Practical example: application to the Spanish energy system

The Spanish energy system is one of the most successful cases of RES integration, particularly as regards wind and solar power (around 16 000 MW of wind and close to 1 500 MW of solar energy in 2008, compared to a peak demand of under 45 000 MW and a governmental target for 2016 of 29 000 MW). Its success is attributable to an FIT scheme, which has been reformed several times in a number of ways (Pérez-Arriaga et al., 2006; Del Río, 2008).

Under the allocation criteria in force at the time of this writing, the burden of extra costs incurred for RES amounted to around 8 % of the electricity tariff in 2008 (roughly 2.4 billion euros compared to a total cost of supplying electric power of around 30 billion euros), and according to CNE estimates, will come to around 15 % in 2016 (over 4.5 of a total of 35 billion euros).

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[13] In the case of gas, it could be also collected via the access tariff, as well as it could also be considered to establish the levy for all the fuels, including electricity and gas, and removing the charge from the access tariff.

[14] This is often the case with the settlement of access tariffs.

The proposal set out in this paper can be illustrated with an example based on the estimated overcosts for the equivalent premiums to be paid for these so-called special regime technologies in financial year 2008, calculated as the difference between the expected cost at the facilities and the expected final market price. Table i gives a rough estimate of the volume of the premiums in this year.

Table i. Estimated special regime premiums in 2008 [source: CNE]

Technology	Equivalent premium (Mill. EUR)
Category a	
Cogeneration	433,465
Category b	
Solar	408,941
Wind	1100,294
Small hydro	113,300
Biomass	147,951
Renewable waste	14,247
Total	**2218,198**

The methodology provides for the distribution of the overcost incurred for special regime premiums and, for reasons of consistency as discussed below, of the cost of reducing the tax on biofuels, set at zero[15].

As explained earlier, the appropriate procedure would be to distribute the total extra cost of renewable energy premiums and tax reductions among all the energy vectors in proportion to the amount of the total national energy consumption accounted for by each.

The proportions that would be used to distribute the total extra costs of furthering renewable energy may be taken from the Ministry of Industry, Tourism and Trade (2008), as follows:

Table ii. Final energy consumption in 2006-2016

	2006		2011		2016	
	ktep.	Structure	ktep.	Structure	ktep.	Structure
COAL	2265	2,1%	2021	1,8%	1970	1,6%
OIL AND OIL DERIVATIVES	54090	51,3%	55859	48,6%	56936	46,1%
GAS	16457	15,6%	19094	16,6%	21914	17,7%
ELECTRIC POWER	21511	20,4%	24475	21,3%	27323	22,1%
RENEWABLES	3736	3,5%	6757	5,9%	9075	7,3%
Total energy use	**98059**	**93,0%**	**108206**	**94,1%**	**117218**	**94,9%**
Non-energy use:						
Oil and oil derivatives	6916	6,6%	6381	5,5%	5845	4,7%
Gas	441	0,4%	441	0,4%	441	0,4%
Total final use	**105416**	**100,0%**	**115028**	**100,0%**	**123504**	**100,0%**

[15] Established in Act 2/2005 of 18 November, whereby EU legislation is enacted into Spanish law, including the directives on taxation of energy products and electric power, common tax regulations applicable to parent companies and subsidiaries in different member countries, and tax regulations for cross-border payments to pension funds within the European Union.

Based on the percentages estimated for 2011 and the figures in Table i, the amounts that should be allocated to each type of energy consumption, including the electricity grid access tariff, would be as shown in the table below.

Table iii. Amounts to be attributed to energy consumers

Final energy consumption	Structure (%)	Relative structure (%)	Assignation (Mill. EUR)
Coal	1.80%	2.04%	**52.107**
Oil and oil derivatives	48.60%	55.04%	**1406.894**
Gas	16.60%	18.80%	**480.544**
Electricity	21.30%	24.12%	**616.602**
Total	88.30%	100.00%	**2556.147**

One direct consequence of applying this methodology is that the percentage of electric power prices for consumers attributed to the costs deriving from mechanisms to support RES would decline to one fourth of the present figure.

5 CONCLUSION

In energy and transport systems in which electricity generated by new RES installations and the use of biofuels have a growing contribution to total consumption, the allocation of the costs incurred to support RES is a key aspect of tariff design. The methodology described in this paper addresses that issue. As it is deeply discussed in the paper, the solution proposed is consistent with the main regulatory principles that should govern tariff design, maximising allocative efficiency and equity. Thus, the RES subsidy-driven extra costs distribution is ruled according to the marginal cost pricing and cost-causality principles.

The methodology entails that all final fuel consumers should pay the costs of RES promotion programmes in proportion to their final consumption, regardless of the origin of renewable energy (such as biofuels or wind or solar energy).

This approach is put forward also as a necessary solution to prevent disproportionate and, as shown, inefficient and unjustified electric power overcharges.

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