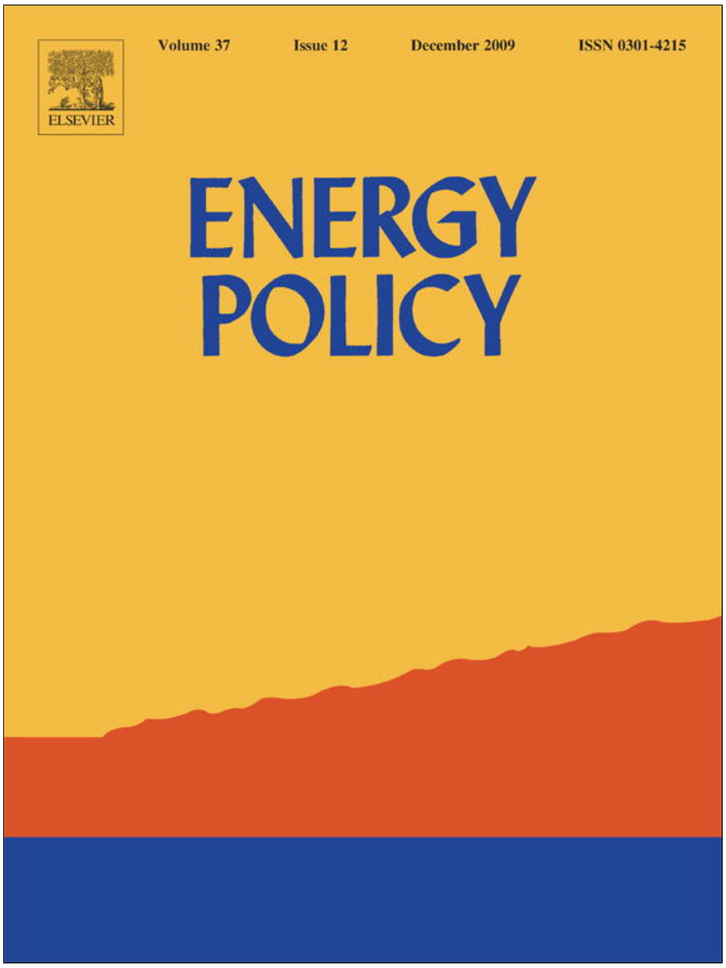
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Basic concepts for designing renewable electricity support aiming at a full-scale transition by 2050

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ABSTRACT

Renewable electricity supply is a crucial factor in the realization of a low-carbon energy economy. The understanding is growing that a full turn-over of the electricity sectors by 2050 is an elementary condition for avoiding global average temperature increase beyond 2 °C. This article adopts such full transition as Europe's target when designing renewable energy policy. An immediate corollary is that phasing-in unprecedented energy efficiency and renewable generation must be paralleled by phasing-out non-sustainable fossil fuel and nuclear power technologies. The double phasing programme assigns novel meaning to nearby target settings for renewable power as share of total power consumption. It requires organizing in the medium term EU-wide markets for green power, a highly demanding task in the present context of poorly functional markets in brown power. The EU Commission's 2007/2008 proposals of expanding tradable certificates markets were not based on solid analysis of past experiences and future necessities. The keystone of sound policies on renewable electricity development is a detailed scientific differentiation and qualification of renewable electricity sources and technologies, for measuring the huge diversity in the field. We provide but structuring concepts about such qualification, because implementation requires extensive research resources.

Support for renewable electricity development is organized via feed-in prices or premiums, and via quota obligations connected to tradable green certificates. Green certificates are dependent on physical generated renewable power, but separable and no joint products. Contrary to conventional wisdom we argue their separation in cost analysis but firm linking during trade. A few graphs illustrate the importance of assigning qualities to different renewable power sources/technologies. Feed-in systems based on an acceptable qualification perform generally better than certificate markets imposing uniform approaches on a very diverse reality. For a similar reason, uniform and undifferentiated taxation of non-sustainable energy sources cannot replace renewable energy support schemes capable of differentiation.

1. Introduction

Effective climate change policies make it urgent to phase-out, by the middle of the 21st century, non-sustainable – nuclear and fossil fuel – electricity generation, even with carbon capture and storage and to phase-in renewable-based generation. This goes far beyond creating a playground for RES-E. To make sure that this process is carried out in an economically efficient way, it is important to design a regulatory market framework that can accommodate the complexity of this enterprise; this leads us to give market forces a central role. Now the current debate on market-based instruments usually does not rise to this task since it tends to neglect the complexity resulting from differences in the essential qualities of renewable sources/technologies. Often it relies on ideological argument, and frequently ignores rent-seeking by incumbents (Lauber, 2009).

We develop concepts for classifying renewable sources and technologies by quality and we show how they justify different costs and necessitate fine-tuned regulatory treatment. Implementing the concepts asks for more extensive international study and agreement. Once the qualities and their effects on maintaining RES-E based electricity supply systems are worked out, the

Abbreviations: EE&SRE, Electricity efficiency and sustainable renewable electricity; FIT, Feed-in tariff; GO, guarantee of origin; IPCC, intergovernmental panel on climate change; LRMC, long-run marginal cost; NSE, non-sustainable electricity; RE, renewable energy; REC, renewable electricity certificates (see also RPS, TGC); RES-E, electricity from renewable energy sources; RO, renewables obligation (in UK); ROC, renewables obligation certificate; RPS, renewable portfolio standard; SRMC, short-run marginal cost; TGC, tradable green certificates

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rules and instruments of a fine-tuned market framework can be set-up.

In Section 2 we sketch the context of our analysis, being the phasing-in of EE&SRE electricity generation and supplies while phasing-out NSE sources and technologies by 2050. Section 3 continues with investigating what policy approaches are consistent with the full transition task, with attention for the role of targets, for the necessity of organizing RES-E markets in the longer term and for the double phases embodied in a full transition scenario. Section 4 discusses the necessity of an extensive differentiation and qualification of RE sources and technologies, also considering project ownership. The characteristics of physical power and of green certificates are discussed in Section 5, delving further into the short-term and long-term relationships between both products. Section 6 takes up the analysis of the main RES-E support systems, FIT and tradable certificates, illustrating their functioning and effects with graphs. The last part of Section 6 is an epilogue that introduces some further points for debate when policies are designed for the full transition of the EU electricity sector to high efficiency and renewable energy by 2050. A brief conclusion rounds this article.

2. The full transition to RES-E by 2050 as Europe's policy target

Before embarking on detailed designs of policies addressing any societal issue of significance, society and its political authorities should clarify "what" is to be realized by "when". Such clear goal setting supports convergence after society has agreed upon the need for change. In practice however, political authorities are hesitant to adopt reforms as radical as those required by climate change which would have to confront the whole "techno-institutional complex" of carbon lock-in (Unruh, 2000). It is therefore necessary to familiarise decision-makers with the steps needed to be taken. Scientists play a role in this process by sketching out the steps, by exploring the implications of adopting – or not adopting – them, and generally by suggesting the most suitable instruments for realizing the reforms (Kingdon, 2003). We want to contribute in this sense to the faster transition towards a sustainable energy economy.

At present there exists no clarity and *a fortiori* no consensus on the future structure of the European electricity sector. Most informed observers agree that the carbon emissions of power generation in the future have to come down drastically, and targets for 2020 are part of the December 2008 energy and climate package deal between the European Commission, Parliament and Council. Such a step-by-step and near-term approach falls however short of meeting the challenges towering over us. Investments in power generation and in electricity grids last for several decades (mostly 40+ years). From experience we know that disruptive technological transformations also span several decades (Grübler, 1998; Unruh, 2000). Both facts confirm that change not only has to be drastic but also urgent to avoid lock-in into new non-sustainable power supply systems (Stern, 2006; Baron, 2008). Incumbent companies are rarely the source of radical innovations which originate mostly with entrepreneurial challengers. Usually incumbents enrol the support of politicians and administrations for maintaining their dominant design and positions (Unruh, 2000, 2002).

We agree with studies concluding that Europe (as the other developed industrial states) needs to realize the full transition to zero carbon electricity systems by 2050. This is a clear goal for rallying political, economic, technological, educational and other societal developments during the next 4 decades. IPCC (2007) and well-informed experts (Copenhagen declaration, March 2009) deliver growing evidence that the lowest possible greenhouse gases concentration trajectory should be adopted. Such a trajectory implies for the EU about 80–95% reduction of greenhouse gas emissions overall by 2050. For the electricity sector the highest reduction goal of 95% is then evident because of the many opportunities to generate carbon-free power.

Once the greenhouse gas reduction goal is adopted, the EU has to make clear what technological revolution will realize such a goal. Except for minor contributions by fuel substitution and probably inefficient (Page et al., 2009) carbon capture and storage as an end-of-pipe option, two main low-carbon technologies compete: nuclear fission and renewable power. Despite the poor record of two major campaigns levelling the path for civil nuclear power (Atoms for Peace in the 1955–1970 and "Solving the oil crisis" after 1973), some industrial interests still spread the idea atomic power is an essential technology for the future. Independent researchers are generally very critical of the nuclear option (Mez et al., 2006) and argue the option fails on all sustainability criteria and is the opposite of real sustainable development (Verbruggen, 2008; Jacobson, 2009). While a tremendous substitution of base-load fossil power generation by atomic power could reduce the emissions of carbon dioxide significantly, nuclear implies high risks of a different kind but not necessarily of lesser extent and danger than climate change risks (Beck, 1992). In contrast to statements by Stern, IPCC and IEA that the widest range of technological portfolios should be developed, there is evidence that several components of such portfolios are antagonistic and internally inconsistent (Verbruggen, 2008). For a safe climate and energy future the electricity efficiency and sustainable renewable electricity (EE&SRE) technological cluster is the only promising one.

The central task of EU electricity policy can therefore be summarized as: phasing-in EE&SRE while phasing-out non-sustainable electricity (NSE) sources and technologies over the next 40 years. What does this imply programmatically for the consumption, generation and transmission of electricity?

First, the realization of unprecedented electricity end-use efficiency is a prerequisite for making the full transition to sustainable renewable energy affordable. Turmes (2008, pp. 23, 33, 159) adds the efficiency dimension to the RE Directive discussion, but far more efforts and policies are necessary. It is doubtful whether during the transition, sustainable RE sources can match the present-day energy-intensive techniques and lifestyles of the wealthy nations.

Second, no new constructions of any nuclear or large-scale fossil fuel power plants should be allowed in the EU, and phasing-out existing ones is on the agenda for the next 40 years. Such a programme represents an enormous inroad in non-sustainable business practices and frees huge capital, human and natural resources, also with respect to R&D (e.g. terminating the nuclear research boondoggle; limiting carbon capture and storage to small-scale systems). New fossil fuel generation capacity is gas-driven and limited to cogeneration units and to specially designed balancing power plants providing supplementary and back-up electricity for the more variable, stochastic and intermittent RES-E sources.

Third, the electric power grids have to be transformed from giant pyramidal structures to diamond-like multi-poled and multi-faceted structures, better equipped for alternating flow directions and incorporating more decentralized energy storage facilities.

Such clear and radical 2050 goals (often called "long-term" but due to inertia and lock-in their realization necessitates immediate actions) have many consequences for all present-day and consecutive decisions regarding electricity supply, in particular regarding RES-E. The above programme of a full transition by 2050 is not new, but specified by several authors (Scheer, 2001; Bradford, 2006; Patterson, 2007; Lund and Mathiesen, 2009; Peter and Lehmann, 2008). The clear 2050 goals and the phasing-in EE&SRE while phasing-out NSE are not yet adopted by major decision-makers, whereas several large power companies and several governments in the EU (e.g. France, UK, Italy, ...) are betting on the nuclear oracle for the third time. Also far from settled are answers to the policy questions of how and by whom the transition should be accomplished.

3. What policy approaches are consistent with full RES-E transition?

If the recommendations by IPCC and other scientific reports are taken seriously, the "urgent and drastic" transition of the electricity systems in Europe and elsewhere is on-top of the energy policy agenda. This implies a number of "urgent and drastic" changes in the policy discourse. First the role of intermediate targets for attaining the final goal is put in perspective. Next we discuss how markets and market forces can contribute. The section concludes with emphasizing the nature of the transition process as phasing-in EE&SRE while phasing-out NSE.

3.1. *The role of targets in structuring policies*

Setting targets is a standard component of important political processes, as strategic management[1] literature and experience recommend. Macroeconomic, development, environmental, etc. policies rely upon specified targets set out for the future. Also international agreements centre on target setting as the famous 0.70% of GDP for official development aid and the Kyoto–Bali–Copenhagen process showcase. Numeric targets are very helpful in mobilizing people and resources and in monitoring progress. However monitoring is not enough when commitments and tools for enforcing target compliance are lacking (see the 0.70% target agreed upon in 1970/2002). In the Kyoto process target setting is at the top of the agenda. A COP/MOP conference seems successful when more countries agree on sharper targets (accompanied by wooing and booing rounds). Target setting however is not very helpful when targets cover a reality that is too vast, complex and dynamic, as they do in the Kyoto process (Prins and Rayner, 2007). In the best case they may create a positive stimulus; in the worst case they affect progress towards the goals of the policy in a perverse way.[2] They may also simply remain ineffective.

Politics for the promotion of renewable energy also fall back on target setting. One is accustomed to RES-E targets as a percentage of total electricity generation or consumption in future years, while in most power systems non-sustainable electricity prevails (base-load coal and gas plants, nuclear). Such target setting involves perverse aspects. The absolute success of RES-E output is linked to the size of the power systems, including NSE generation, whereas the size of the power systems should shrink rather than continue expanding.[3]

Targets may turn into a negative element when set and pursued in a myopic way forgetting their role as stepping stones towards an ultimate goal, thus when decisions in the near-term are creating barriers and burdens for a full overall optimization of the transition of the power systems. A set target can disturb or block the development of sustainable RES-E technology when the latter is booming much faster than forecasted at the moment targets were adopted. In the opposite case, when politicians fear their nearby overall target fetish will not be accomplished, they are willing to stretch quality control on RES-E (see Section 4), e.g. by including dubious co-incineration activities. All this is a plea to assign to targets but a secondary role in following-up progress in specific circumscribed fields.

A major problem with targets is the distribution of an overall common target over the constituents that must contribute to its realization, like the assignment of renewable energy percentage targets to EU member states in the 2008 draft directive on renewable energy (CEC, 2008b: Annex I). From an economic efficiency point of view[4] assignments should be proportionate to the marginal costs carried by the various member states in meeting their specific target. In practice it is extremely difficult to realize such optimal allocations. First there are theoretical and practical problems in estimating the true marginal costs of supplying RES-E in the various member states. E.g. marginal costs depend on resource endowments that are poorly inventoried in various places, on stochastic natural factors that may be affected by long-term trends such as climate change, on technological invention and innovation that cannot be fully assessed over the period the targets are set, on economic business cycles, on the kind of regulatory treatment of NSE, EE&SRE, etc. When setting a global target for the whole RES-E portfolio the relevant marginal cost is a weighed average of the marginal costs of the various composing sources and technologies, aggravating the measurement difficulties. Second, in burden sharing conventions political processes behave along other rationalities than theoretical optimization schemes. Politics often implies the application of simple principles such as symmetry, the introduction of criteria such as GDP per capita (as in the new renewable energy directive), the reflection of relationships of power or results that are best explained by the theory of coalition building.

An alternative approach suggested by Jefferson (2008) and Fouquet and Johansson (2008) is to avoid target assignment to individual participants and to define the common target as a common duty for all. This means that other policy instruments have to be designed to operate at the common level for meeting the goals (e.g. joint research and investment programmes). Because this direction is not taken by the EU it is not discussed here.

3.2. *Markets for green power*

Because administrative and political processes fall short in designing optimal target assignments over a constituency, market mechanisms are called upon to allow reshuffling of physical activities by participants to obtain mutual benefits. E.g. a member state with an excessively high target can buy RE-output from a member state whose target is comparatively too low, both benefiting from the trade. The aggregate benefits of such trade can be labelled either as proof of market success, or as a measure of political failure in designing and assigning the right targets. Because of limited information, uncertainty, and dynamics market

[1] Remember the acronym SMART: targets should be specific, measurable, accepted, realistic and timed.

[2] E.g. the economic crisis since 2008 means that many Annex I countries will meet the Kyoto reduction targets for greenhouse gas emissions without significant technological mitigation efforts. Moreover, the connection economic crisis with meeting climate policy targets installs wrong perceptions. Targets in TGC/quota systems set upper limits and thus may inhibit RES-E development.

[3] It is therefore positive that subsidies for the development of RES-E sources are mostly charged on the end-users of NSE through the price setting of suppliers, having a choking impact on the demand for electricity.

[4] Next to efficient, such allocation is also effective. It can be argued as fair because uneven endowments and differences in past efforts are taken into account.

exchanges can bring additional benefits. But minimizing the need for such exchanges in artificially constructed markets (like markets for carbon emission allowances and for RES-E generation commitments) is testimony of political performance in the design and set-up of such constructions.

Also, the deep and wide technological and industrial transformations of the power sector required by its full transition ask for the involvement of numerous private and public decision-makers. The number, diversity and small size of many RES-E investments and operations, and their interactive links with energy efficiency and load management, are such that market forces may play a beneficial role. Properly defined markets are institutions facilitated and regulated by public authorities to frame economic exchanges freely[5] engaged by (mainly private) parties for their mutual benefit. Such institutions perform more efficiently under conditions of workable competition.

Installing and safeguarding workable competition requires enlightened regulation, in particular when the facilitation of markets equals their top–down design and construction. "Levelling the playing fields, designing the rules of the game and enforcing the rules" are all better done when conditions for the players can be harmonized, when transparency is maximized and when collusion or dominance by players are absent. RES-E markets will interact intensely with NSE activities which are hardly a showcase of free competitive markets (Glachant and Finon, 2003; Thomas, 2003, 2007; Domanico, 2007). Is it feasible to set-up exemplary RES-E markets without the prior instalment of competitive conditions on the incumbent electricity companies? When NSE activities remain monopolized, what special provisions and exemptions are necessary for a workable competition in newly created RES-E markets?

The depth of the transformations in generating and consuming electricity asks for disruptive new inventions, technologies and practices in the fields of electricity efficiency, RES-E technologies, power system integration and grid network balancing. Next to dedicated R&D policies, RES-E development policies must advance innovative technological developments (IEA, 2008; Jacobsson et al., 2009). The full range of RES-E technologies needs parallel development, rather than only sequential launching depending on short-term profit calculation, due to the decade-long time-span of technological innovation cycles against the backdrop of "urgent and drastic change" required by climate change. Autonomous market forces show a preference for immediate money-makers disregarding their environmental performance and the responsibility for the (very) long-term—and even disregarding the opportunities offered by some technologies over the long-term. This myopia is not simple to correct because such a correction requires a neat balance between autonomous market forces based on self-interest and enlightened regulation by public authorities. Fri (2003) plainly argues the crucial role of demand pulling market forces in driving disruptive innovation, in particular regarding energy efficiency and distributed generation options.

The width of the electricity sector transformations in Europe asks for addressing the full RES-E resource base, including imports from neighbouring countries with exceptional vast resources (Norway, Mediterranean basin, Eastern Europe, Russia). This coverage and the interaction with constituencies outside the EU again point to the necessity of performing market structures for trade and exchange of physical RES-E.

[5] This is the right meaning of 'free' markets; since the advent of "casino capitalism" (Strange, 1986) many interpreted 'free' as deregulated and not submitted to a sufficient set of rules, a practice which led to the financial crisis of 2008.

3.3. Phasing-in EE&SRE while phasing-out NSE

The phasing-in EE&SRE while phasing-out NSE process is intimately related to the most crucial issue of any electric power system: the integration of the various generators and grid components into a synchronous ordered system. "Grid access" is a common term in the RES-E Directive proposal (CEC, 2008b, art. 14) as in other literature (Langniss et al., 2009). The term focuses attention on the entry doors to the power systems while actual integration occurs behind those doors, as expressed in Article 16 of the 2009 RE Directive ("Access to and operation of the grids") (Directive 2009/28/EC).

The transition to sustainable power systems will be successful once the stalemate between independent power producers and centralized (incumbent) power generation oligopolies is resolved in favour of the former. This is a big change given the incumbents' historical dominance and their massive financial and organizational power. Nor is this in line with the current policies by the European Commission. As Thomas (2007, p. 10) argues,

> The Commission seems to have an agenda in favour of creating strong European companies to compete in world markets coupled with a belief that it can handle oligopolistic markets (...) this does not seem a good policy. Experience to date suggests that markets outside will not be profitable or attractive to European companies and it is questionable whether the Commission really does have the skills, the political will and the power to deal with oligopolies.

Public policies and policy instruments should foster the growth of independent power producers and address and contain the power of the power oligopolies in Europe. How effective the third internal energy market package of the EU will turn out is still pending. Up to now the energy market is not a common market where essential conditions for a workable competition prevail (Glachant and Finon, 2003; Thomas, 2007; Patterson, 2007). Analysis and proposals that are contingent on the existence of competition in the power markets are therefore to be classified as elusive mirages.

We discuss four relevant aspects of phasing-in EE&SRE while phasing-out NSE. First, cost analysis. Our reading is that full electricity supply from RES-E relying mostly on new plant is, and will be for some time yet,[6] a more expensive option then the present supplies[7] based mainly on fossil fuels, nuclear power and large-scale hydro stations which in many cases have been written off and whose large environmental costs are not reflected in their prices. The present economy of commercial energy-intensive production, consumption, transport, recreation, etc. does not allocate its resources in an optimal way. Commercial energy intensities must come down more drastically then ever thought, and efficiency improvement is crucial for this to happen along with shifts in activities (affecting lifestyles). Deployment of ever improving electricity efficiency is a prerequisite and a

[6] Individual RES-E sources/technologies will vary in reaching "unreformed" costs of NSE. Even for wind-poor Germany, it is estimated that for the past few years, cost-savings by wind energy in Germany is higher than the subsidies for the Renewable Energy Sources Act (Weigt, 2009), and wind power today is quite competitive (Milborrow and Harrison, 2009). Grid parity for photovoltaics may be reached in Europe during the next decade (Farber and Rogol, 2008). Eventually all renewable sources are likely to become cheaper than NSE (Bradford, 2006). Wenzel and Nitsch (2008) expect this for Germany by about 2026. See also Section 6.4.

[7] Living on harvested flows brings higher spending on labour time and other economic resources than freely tapping stocks which are inherited treasures (e.g. illustrated by high employment ratios of most renewable energy deliveries). While negative externalities of RE are fewer, and the ones that exist are internalized quicker or block the resource development, i.e. the bills of RE have to be paid fully and upfront.

natural ally for distributed small-scale installations, owned and operated by final customers. Additional supplies on-top of own generated power should come where possible from local sources that can be developed, owned and operated by local companies (Hvelplund, 2008). The large-scale RES-E systems highly favoured today (Patterson, 2007; Lauber, 2009) should be designed as the third circle around end-use electricity demand, not as the substitute for fossil fuels in the present obese energy consumption systems.

Second, the integration of independent small-scale distributed and local sources into the power systems should bypass confrontations on the places and times favoured by the incumbent power companies. Priority access for delivery to the grid should follow the qualification ranking of RES-E generation (see Section 4 below). The remuneration of RES-E should not depend on "grid access" terms or on other conditions and events determined by the owners of integrated power systems. Such dependency is similar to heating and cooling simultaneously: first RES-E gets support, next RES-E is stripped from (part of) the support by the ones that were charged with paying the support (Ropenus and Jensen, 2009). FIT systems can be designed to match the independence perfectly when RES-E suppliers deliver to the grid at ex-ante fixed prices per kWh, avoiding take-back mechanisms for grid access. But the issues of grid access and integration are catapulted back on-top of the agenda if the purchasing obligation terminates along with the special FIT for independent producers. The support via premiums and via REC or TGC is an add-on to the obtained sales price of the kWh, and here the issues of integration are vivid all time long.

Third, imposing the full burden of integrating growing RES-E deliveries onto the actual power systems (incumbents) is the most efficient way to induce the power system owners and operators to learn how to adapt and rebuild their systems for accommodating the transition. Vice versa, if they can roll-off whole or part of the expenses and difficulties on RES-E suppliers this will obstruct and delay the EE&SRE phase-in/NSE phase-out process.

Fourth, adopting clear principles on charging the costs of system integration will simplify Article 16 §3 of the 2009 RE Directive (Directive 2009/28/EC). Good intentions enshrined there in terms of "objective, transparent and non-discriminatory criteria taking particular account of all the costs and benefits associated with the connection of these producers to the grid…" sound good but are difficult to materialize when the power balance between small-scale distributed generators and incumbent oligopolies is very unequal and when NSE is not charged the price of its risks and externalities. Therefore §4 "Where appropriate, member states may require transmission system operators and distribution system operators to bear, in full or in part, the costs referred to in §3" is better replaced by a text such as contained in Amendment 136 §4 of the European Parliament:

> Member states shall require transmission system operators and distribution system operators to bear the costs for grid reinforcements related to the extension of both large scale and small scale renewable energies necessary to achieve the minimum national target established in Annexes 1.A and 1.B. These costs will be authorised by the national regulators and spread across all energy consumers (European Parliament, 2008).

The full liability of the integrated system owners and operators must be stated firmly, not just with regard to the 2020 targets, but up to and conceived from the full transition of the power systems. The EU would do well to skip the loose treatment of issues arising from unequal power relations as "discrimination".

4. RES-E qualification

The full deployment of EE&SRE requires well-designed policies, regulations and instruments for being effective, efficient and fair. For meeting such demanding criteria regulations must be fine-tuned in addressing the various components and aspects of the transition process. A most important first step is the comprehensive and consistent qualification of what sustainable RES-E means to be. RES-E is too general a category and cannot support a fine-tuned regulation for developing sustainable renewable options.

In practice only preliminary cataloguing and qualifying of RES-E sources exist; thus Directive 2001/77/EC established a list of sources and technologies that are accepted as RES-E for meeting the indicative targets by 2010. The draft 2008 RES Directive was debated extensively on the definitions of various types of bio-energy and led to highly specific rules for calculating the greenhouse gas impact of biofuels (see Annex V of the Directive). Despite much new information and understanding, there is still no comprehensive and consistent catalogue available for all RES-E sources and technologies.

RES-E supply is the result of a combination of RE sources with RE-technologies. Technologies are necessary to harness the sources because electricity is not freely available in nature in a useful way, contrary to other uses of renewable energy—as heat (e.g. solar drying), work (e.g. ventilation, gravity) or light. Technologies are always necessary to harness electricity from renewable sources by collecting (often concentrating) natural energy sources and converting them to power. Storable sources (biomass, water) can be stockpiled between collection and conversion to electricity, requiring storage facilities (e.g. dams). Radiation, light, wind, etc. cannot be stored.

Qualification starts with assigning attributes to RES-E sources and technologies, e.g.:

Attributes of sources:

- Types (e.g. wind, solar types, bio-energy,).
- Density (unit of density varies with RE types, e.g. speed m/s for wind, radiance in Watt/m^2 for sun, GJ-m^3/year for bio-energy, …).
- Variability (flow versus stock character, randomness, intermittency).
- Accessibility (geographical location, distance to end-use centres).

Attributes of RE-technologies:

- Types (e.g. on-shore wind turbines, off-shore wind turbines, photovoltaic cells, concentrating solar power units, fuel cells, …).
- Scale (economies of scale by unit or by number of units, market development).
- Maturity (phase of the innovation cycle: prototypes, demos, first series, pioneer markets; distance to technical perfection).
- Costs (investment, maintenance and operational costs; economies of learning).

In addition to the physical, technical and economic attributes of sources and technologies, there is a regulatory interest to distinguish ownership of the RE-projects, e.g. small/large independent generator generating up to/in excess of own yearly electricity use, local cooperative generating up to/in excess of members' yearly aggregated electricity use, independent power producer for delivery to the grid, power generators with connection to suppliers (mostly incumbents), state, …

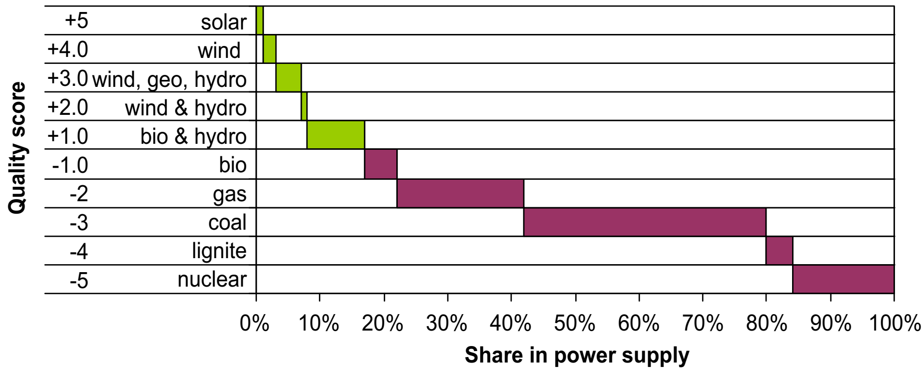

Fig. 1. Phasing-in RES-E/phasing-out NSE.

The attributes allow the classification of 'source–technology' combinations, i.e. RES-E projects and their supplies, in different categories. The second step in qualification is evaluating and ranking the attributes and categories on sustainability criteria. It may prove impossible to find and agree upon detailed sustainability scores. As a substitute proxy one may adopt a limited number of classes to measure sustainability degrees on a 100% scale, e.g. five classes from very low (0–20), low (20–40), medium (40–60), high (60–80) and very high (80–100).[8]

It will take quite some time and effort to develop and implement a practical qualification methodology for generic use and generalized over Europe (and beyond). This type of fundamental and applied research is often overlooked leading to poor regulations. The managers' maxim that "one cannot manage what one does not measure" is also valid here. Investing in a comprehensive and consistent qualification system, ahead of conceiving and debating regulations and instruments, can avoid waste of time and human resources and bypass perverse effects from defective regulations. The discussions during 2008 on the qualities of bio-energy show how important – and how difficult – good qualification work is. Developing the RE catalogues could be a central task for International Renewable Energy Agency (IRENA) founded in January 2009.

When the qualification of RES-E and NSE power generation sources is completed the phasing-in/phasing-out process can be represented and followed by graphs as shown in Fig. 1. The graph reflects the fact that the sustainability of some sources varies with sites and with the technology used to harness them.

5. The relationship physical power–certificates

Two main instruments are applied to support RES-E development: Feed-in tariffs (FIT) and RE certificates (REC or TGC, tradable green certificates, also organized as RPS, renewable portfolio standards). FIT relies on price and REC on imposed quota as incentives for private investors to build and operate RES-E plants (Menanteau et al., 2003). The FIT mechanism is rather simple and transparent (Lauber, 2004; Lauber and Mez, 2006; Langniss et al., 2009). The REC mechanism was new and attracted more debate in the literature (Lovinfosse and Varone, 2004; Mitchell et al., 2006; Kaberger et al., 2007; Verbruggen, 2004). This paper focuses on basic issues such as the actual relationship between physical renewable power and certificates.

[8] A similar classification could mirror the 'performance' of non-sustainable electricity options, with five classes from −100 (absolute non-sustainable) to zero (neutral).

Some authors treat RE-kWh and RECs as joint products (Morthorst, 2000; Kildegaard, 2008; Bode and Groscurth, 2008), or skip the detailed study of their relationship (Agnolucci, 2007). But why consider an assigned subsidy and the subsidized product or service as joint products? Joint-ness in production resides in the production function (technological) characteristics, e.g. an oil refinery deriving a wide range of intermediate and final products from a flow of crude oil.

The assignment of a subsidy to some output creates a contingency of the subsidy on the output. The created virtual certificates are separate products (Fouquet and Johansson, 2008). The value of the created certificate should depend on the qualification of the RE-output it is contingent on (Section 4). When no functional qualification is applied all certificates are handled as if they were of equal value, giving rise to suboptimal support systems with high excess profits (Verbruggen, 2009).

Table 1 provides an overview of main characteristics of the two products: physical kWh and REC. They are of different nature, asking for separate treatment. For example short-run marginal cost analysis attributes other significance to transient kWh than to long-valid certificates. The economics of the physical electricity system and the virtual REC are interrelated in two ways.

First, the supply of certificates is dependent on the expected revenues from the sales of the RES-E output. This expectation differs for incumbent power companies and for independent producers, mainly for small ones. The latter incur risks from volatility and in particular from falling prices resulting from oversupply (Mitchell et al., 2006), a risk which incumbents can largely control by holding down the rate of quota fulfilment. Incumbents can also better survive periods of low prices due to natural causes (such as abundant rain or wind). Flow RES-E capacities cannot be dispatched individually: the net present value of their investment is affected by average expectations on revenues from kWh sales. KWh output by stock RES-E capacities (i.e. those which are routinely subjected to storage) is better to control, but for independent and small-scale generators optimizing their output in accordance with the ups and downs of integrated power systems is more hypothetical than real. Therefore the expected revenues from their sales to the grid are also based on long-run costs instead of on short-run costs.

Second, when certificates become numerous and get high prices, the certificate bill grows significantly. The bills are charged to electricity end-users, something that reduces demand for power, especially in the long-run. This may be considered as a positive effect when demand is reduced through higher efficiency and not by deprivation of the poorest deciles of the population. However, most of the money is cashed by incumbent companies for spending mainly on non-sustainable projects, making the picture more troublesome.

Table 1
Main characteristics of the product electric kWh and of the product certificate.

Electric kWh	RE-certificate
Physical phenomenon, comparable to pressure in a water network (Stoft, 2002)	Virtual record in electronic databases, comparable to a bank account
Transient: a kWh is created and used in almost real time	Non-perishable, except by convention (e.g. 365 days validity)
Non-storable (can only be withheld during moments of time in capacitors)	Stored in electronic registers; bankable duration is nowhere shorter than one year
A kWh is the elementary component of integrated, highly extended and dynamic, power systems, covering a wide diversity of producers and consumers	A certificate is a means to fulfil a quota obligation designed by regulation, with the quota usually increasing in annual steps that make up trajectories of RES-E-development
Exchange of kWh needs permanently balanced (phased) interconnected grids	Exchange of certificates needs reliable standardized registration and procedures
Commercial value of the kWh varies with:	Commercial value of REC varies with:
• Instantaneous, transient time. • Place of delivery. • Reliability of kWh delivery at right voltage and frequency. • Liability of supply: delivery on demand and non-delivery when not demanded (varies widely for different RES-E sources).	• Year or longer periods (banking). • Juridical area (member states). • GO procedures checking REC validity. • RE targets or obligations and the degree to which they are fulfilled in respective years.
Sustainability identified by qualification of resources, technologies and ownership	Sustainability value derived from RES-E qualification

Separation of both products occurs when countries buy certificates from other countries to meet their RES-E quota without shipment of physical RES-E. But regulators can also mandate that both must be linked permanently, i.e. traded certificates own no value without the physical shipment of power. The latter approach is necessary when the 2050-goal is the full transition of all European power systems to RES-E. When in 2050 all electricity consumption in all EU member states is renewable, states with shortfalls in domestic generation have to import physical power from states with a surplus. GOs then accompany physical shipments for revealing the sustainability value of the electricity. As such they complement the physical trade in electric power, as the latter is based today only on the characteristics of power highlighted in the first column of Table 1. When the final market of renewable electricity must be real, one can question the setting-up of European markets in virtual electronic certificates during the transition.

6. RES-E support systems

This section provides an overview of the main support mechanisms FIT and REC, highlighting a number of issues discussed in the literature. The discussion how a co-ordinated EU support policy can be set-up in a perspective of the full transition of the EU power systems by 2050 will be dealt with in a later article.

6.1. *Salient observations about existing RES-E support systems*

It is assumed readers are familiar with the support systems applied in the EU. The main ones are feed-in support (e.g. Germany; Lauber and Mez, 2006; Jacobsson and Lauber, 2006; Hirschl, 2008), Premiums (e.g. Spain; del Rio and Gual, 2007); and Quota obligations combined with certificates as in the UK's ROCs (Mitchell et al., 2006) or tradable certificates in Flanders (Verbruggen, 2004, 2009), Sweden (Kaberger et al., 2007), Italy, Poland and Romania. Except for the crucial issue of RE integration in existing power systems, premiums are similar to FIT and will not be discussed in detail here. One peculiarity is that Spain's system of premiums attracts mostly incumbent power generators, while small and independent producers opt for a feed-in tariff, the latter being less profitable but more secure (Ragwitz and Huber, 2007).

Table 2
The support systems FIT and REC compared on essential properties.

Properties:	Type of support system	
	FIT, feed-in tariffs	REC, certificates
Role of targets (quota)	Indicative (not an upper limit), regularly surpassed in Denmark (until 2001) and Germany	Decisive (work as a cap which may not be fulfilled—e.g. UK only for two thirds)
Integration in power systems	Fully solved for RES-E side at least during period of FIT support (Germany: usually 20 years). Purchasing obligation can exist independently of FIT	Not addressed-unsolved
RES-E qualification	Addressed but extension and improvement feasible (EU wide?)	Neglected by design; poor steps of "banding" (UK since 2008 Energy Act c. 32D)
Generator cost coverage and profits	Guaranteed cost coverage for "well-managed plant"+Ricardo rents	Electricity price+rents+excessive profits+risk premiums
Entrepreneurs	Independents, local, open to small scale projects	Incumbents with big projects dominate
Technological innovation	Full-range diversity and continuous improvement by dosed support	Cheapest short-run, hit the money and run options shunting innovation strategies
Transition to renewables	Usually supportive	Usually acting as choker
Distributed generation	Frequent due to many small plants	Tendency to concentrate generation in big plants
Termination of support	At time of expiration date for FIT (usually set legally)—e.g. 20 years), or when support becomes irrelevant (possibly temporarily) because power prices rise above FIT level.	Support terminates at (usually pre-set) date at which renewables obligation expires, or when price of certificates falls to zero

Table 2 provides an overview of the performance of FIT and REC on some essential properties.

6.2. *FIT systems*

A well-designed FIT system is based on a consistent and comprehensive qualification of RES-E projects. Although qualification is subject to significant improvement, German FIT success is mainly the result of a careful categorizing of RES-E sources and technologies (Jacobsson and Lauber, 2006; Wenzel and Nitsch, 2008; Langniss et al., 2009).

For every well qualified source/technology category the *optimal* FIT mechanism functions as shown in Fig. 2. The supply of RES-E by the one qualified RES-E category is represented by an upward-sloping long-run marginal cost curve. The cheapest section of the supply is profitable at the average electricity price. Then follows the MWh-range generating at above that price, but for investors projects are profitable up to the FIT rate. Beyond that range investors cannot cover the expenses and do not file for FIT support. The total FIT spending on this RES-E group is represented by the hatched rectangle, with part of it (triangle MFX) being rents

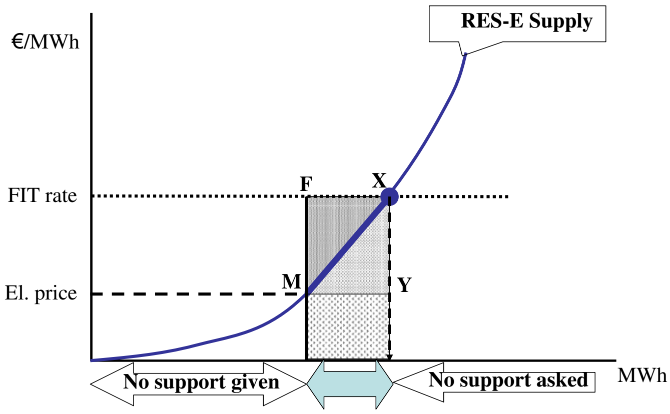

Fig. 2. Optimal FIT for one qualified RES-E category.

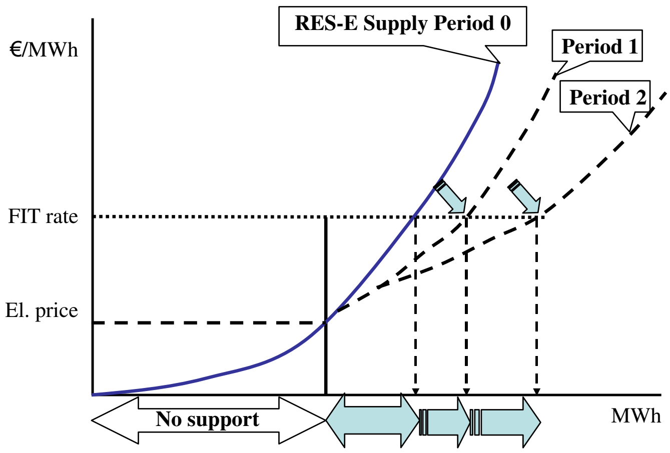

Fig. 3. Support by fine-tuned FIT induces innovation.

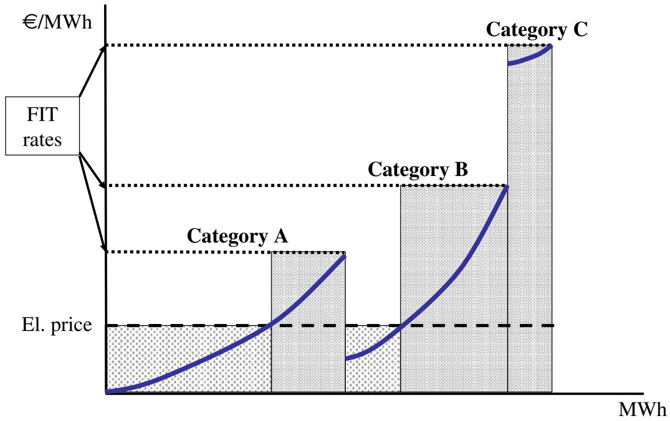

Fig. 4. FITs tuned to three qualified RES-E categories.

paid out to the more efficient generators in the FIT-range. The cost of the support is part MFXY, the extra cost beyond the electricity price.

Fig. 3 shows that FIT provides dynamic incentives to reduce the long-run marginal costs of the projects, because lower costs increases the rent investors can obtain. This will roll the marginal cost (supply) curve down to curve P1, and later to curve P2, etc. The German feed-in law applies declining rate schedules ("degression") to each year's new crop of installations, while keeping them constant for each particular installation. In addition the legislature regularly adjusts FIT rate schedules for future investments when rent payments would grow excessive (as happened in 2008 with PV).

Fig. 4 shows FIT applied to three diverse, qualified RES-E categories A, B and C (one could nickname them biomass, wind and PV). Qualification has ranked A<B<C, something that is reflected in the same ranking of the FIT rates assigned to every category for stimulating projects. For category A, a minority share of the output is FIT-supported; for category B a majority, and for category C all output is supported because this technology is far distant from the market, but highly qualified. The latter may be due to great promise for the future in terms of potential deployment volume and a steep learning curve (as in the case of PV). The qualification provides the scientific foundation for deciding on the FIT rates and so on the resulting short-term development of that RES-E category. Such an approach guarantees what is generally called technological diversity. By fine-tuning the FIT rates the regulator can minimize the total bill of the support provided.

For RES-E qualifications, projects that can generate power below the market price of grid power are barred from FIT access at higher rates, limiting the expenses of the system. Also the rent skimming by such projects is truncated significantly and kept out of the FIT accounts. FIT support in principle lasts until the investment is paid back. After that period the owner can continue generating from the installation at market conditions. Then comes up the crucial issues of access and integration of ever increasing RES-E outputs in power systems not yet designed for the full transition.

6.3. REC systems

Fig. 5 shows the market for RES-E certificates for a given jurisdiction in a given year. The term year is deliberately added to emphasize that quota are imposed as yearly targets and that storable and non-perishable certificates have a regulated validity of one year or longer.

Demand for REC is determined by regulatory decisions on the size of the quota, i.e. the quantity of certificates that generators, suppliers or consumers of electricity have to submit in a given year, and on the size of the penalty to pay for shortfalls. Demand for certificates is an annual predictable curve (banking for longer periods introduces more flexibility). Because quota on RES-E output are mostly expressed as a percent of total electricity consumption, noise on the predicted curve is due to uncertainty about the evolution of total electricity consumption in the future. But most noise may come from regulatory changes, e.g. regulation may increase uncertainty by allowing import and export of

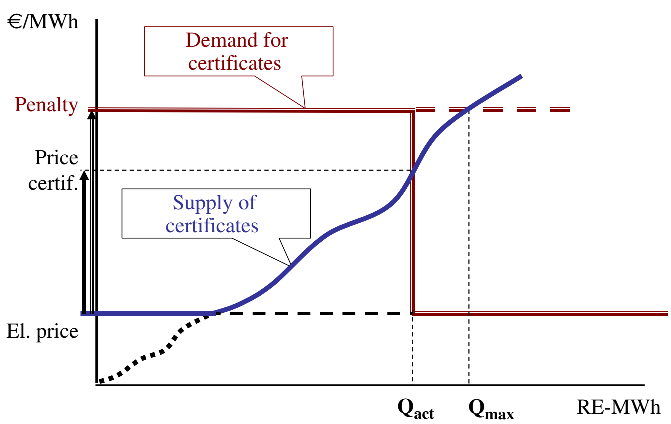

Fig. 5. Certificates market on-top of physical electricity trade.

certificates that may shift the demand for domestic certificates drastically. The few countries that experimented with certificates systems showcase many regulatory interventions (often of doubtful quality), e.g. the law on TGC in Flanders provides for yearly ex-post adaptation of due quota according to the number of certificates that were created during the year (VREG, 2007, 2008). In Italy there is a schedule for regular quota increases in future years currently extending to 2012. The value of the certificates is more or less set ex-post by the regulator who buys certificates that are judged to be in excess and offers additional certificates if needed, thus effectively introducing price floors and ceilings for certificates. For 2009, the reference price for green electricity (certificates and power price combined) is 18 cents/kWh, the actual price in January 2009 was 17 cents. Banding is practiced on a modest level, with off-shore wind and some biomass receiving 1.1 certificates per MWh and geothermal generators only 0.9 (O'Brian, 2009a and 2009b; BMU, 2008; GSE, 2008). For the United Kingdom, the 2008 Energy Act c. 32D allows "banding", i.e. giving more than 1 ROC per kWh for specific sources/technologies (Energy Act, 2008). The Scottish government is currently envisioning as much as 5 ROCs for a MWh of wave or tidal energy (Kearns, 2009).

Supply of certificates is the result of investing in and running plants that generate electricity qualified as RES-E. For technologies that extract energy from flows in nature at very low running costs, fixed capital dominates. For technologies on bio-energy, investment and operation decisions are almost similar to those of fossil fired plants.

Net present values of investments in RE capacities are based on net capital outlays (considering capital subsidies, soft loans, etc.), other expenses, and on expected revenues from physical power outputs over the lifetime of the RE-plant. Revenues are a combination of physical RES-E outputs, averaged electricity prices and certificate prices. Solving the net present value expressions for the certificate price as the independent variable generates the LRMC or supply curve of certificates (Verbruggen, 2004), shown as the curve in Fig. 5 starting with a horizontal segment and then being the LRMC curve of RES-E generation minus the expected revenues of the electricity generated. The supply curve of Fig. 5 is shown as an irregular pattern to express its nature as an amalgamated curve of diverse RES-E sources and technologies.

The concept of short-run marginal costs of RES-E certificates "defined as the short-run marginal cost of production less the spot market price of electricity" (Morthorst, 2000) and adopted by Kildegaard (2008), is not very clear nor very useful. Morthorst (2000) immediately calls in the concept of LRMC to explain the investment decision by RES-E suppliers. Morthorst (2000, p. 1094) expected "substantial price variations" of the certificates assuming a "close connection between prices at the electricity spot market and the price-determination of green certificates". But certificate prices proved to be very stable (Verbruggen, 2009: Fig. 6), adding arguments that SRMC of certificates is an illusory concept.

To highlight the distinctions between FIT and REC support systems, Fig. 6 shows the composite LRMC of the sections of the costs curves of the three categories A, B and C in Fig. 4. When the same output of RES-E is wanted in a REC support system the sum of market and REC price has to cross the supply curve at the top far-right point. The total sum of REC support is shown by the large rectangle above the electricity price line. This support bill could be lowered (significantly) if the REC system would exclude projects that are profitable at the given market price (as shown in Fig. 6 by different patterns of the rectangles). However, for the time being actual REC systems rather solicit all RES-E plants (also waste incinerators from long ago) to share in the due quota, supposedly to create a liquid market for certificates (this is the target fetish, motivated by interest in excess profits), thus preventing the fine-tuning of the instrument. In most countries where REC is applied incumbent power companies or generators privilege the "least cost" RES-E supply options of the lowest quality (waste incineration, co-firing of imported biomass flows in old coal stations, bio-energy-fuelled CHP plants profitable without support, etc.), e.g. Flanders (Verbruggen, 2009), the UK (Mitchell et al., 2006) and Sweden (Kaberger et al., 2007).

The profit logic however will not simply amalgamate the three segments of the supply curves of the RES-E categories A, B and C (Fig. 4) into a composite supply (Fig. 6), but will stretch A where the biggest excess profits occur, shrink B which is less lucrative, and eliminate C because it is too expensive (Fig. 7). The outcome is a shallower LRMC or supply curve, which is used to argue that REC is more cost-effective. With a constant RES-E quota and a working REC market the equilibrium certificates price could fall significantly. Given the structure of existing markets and the likelihood that most of A and B are plants of incumbent generators, the actual certificate prices have the tendency to hang on the penalty ceiling (illustrated for Flanders by Figs. 4 and 6 in Verbruggen (2009)), giving rise to high excess monopoly profits. The exploitive power of free-riders on the system is strengthened by the necessity to continuously increase the quota, and by weak regulators that adapt the quota anyhow ex-post to the wicked outcomes of the TGC system during the previous year (Flanders, Italy).

The excessive profits of REC systems are the basis of insane coalitions among incumbent monopolies and independent RES-E

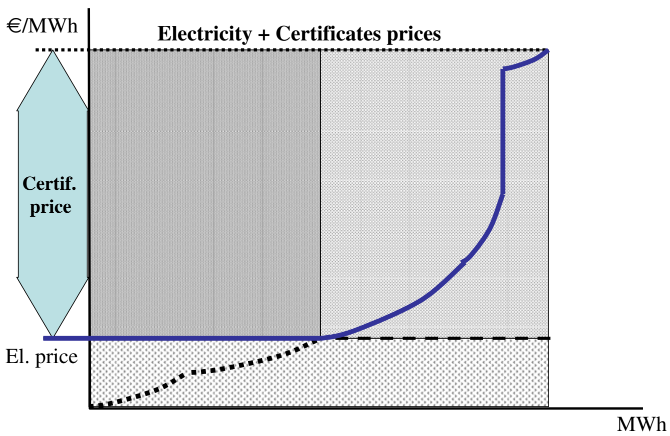

Fig. 6. Amalgamated supply of categories A, B and C, assuming same shares as under FIT.

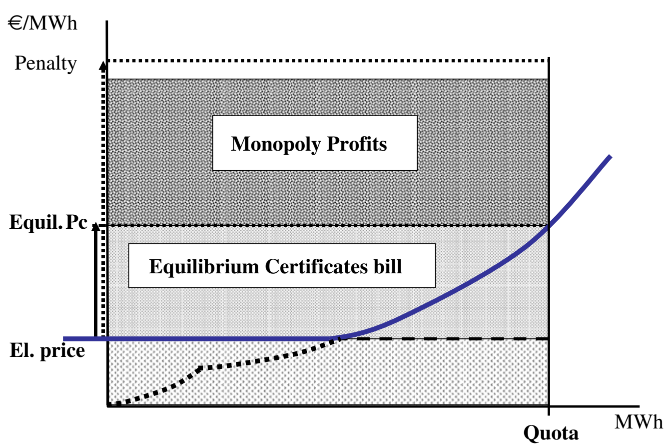

Fig. 7. Amalgamated supply by expanding A, shrinking B, and eliminating C.

producers, both profiting from the money manna falling from the high remuneration umbrella the system provides for. This is evident in the UK as illustrated by the coalition between electricity incumbents and the lobby of wind power firms (British Wind Energy Association) which builds wind farms mostly for the incumbents at outlandish prices, far higher than in Germany or Spain which have much less favourable wind conditions (CEC, 2008a). The UK power incumbents and wind turbine manufacturers joined forces in 2008 to prevent a feed-in tariff or at least to limit it to small installations ("microgeneration") once it was introduced in the 2008 Energy Bill (United Kingdom Parliament, 2008; BWEA, 2008). The excess profits derived from TGC by RES-E generators with more mature technologies such as bio-fuelled CHP are likely produce a similar constellation in Sweden (Bergek and Jacobsson, 2009). The ultimate victims are the most vulnerable consumers and finally the transition to sustainable energy systems itself. If that transition is left in the hands of incumbents, it is likely to progress extremely slowly unless they need substantial volumes of new, specifically renewable capacity and cannot import it. And REC systems are usually dominated by incumbents as small generators and/or their banks cannot take the risk of potentially volatile prices, as argued above.

By effectively restricting the role of small generators, REC schemes[9] also prevent the rise of an important group of supporters of a transition to renewable energy, i.e. people who – often not for purely economic reasons – are prepared to set-up small-scale cooperatives for RES-E generation facilities or to build such installations on their own land or roof and often identify with a transition to renewable energy. These people play an important role in Germany in the coalition that is eager to replace the fossil-nuclear "techno-institutional complex" (Unruh, 2000), thus counterbalancing the clout of the incumbents. By contrast, expensive and ineffective RES-E schemes destroy public opinion support for a transition to renewable energy. Opinion surveys throughout Europe (and also the US, Canada and Australia) show that very strong majorities support the development of renewable energy in the electricity sector, particularly over that of nuclear power or coal (Forsa, 2008; Harris Poll, 2008; Eurobarometer, 2007; SOM, 2006; Civil Society Institute, 2006). But they also show that the public is sensitive about extra costs. Excessive profits and an overall excessive bill will make the transition to renewable energy appear as a boondoggle scheme endangering "economic competitiveness" and hollow out support long before the first price reductions savings due to renewable energy deployment become evident.

6.4. *Can a levy on brown electricity replace RES-E support?*

By public decision-makers (German Parliament, European Parliament) RES-E support is argued as a means to redraw the balance between RES-E and NSE in the electricity market. E.g. "Support systems for energies from renewable sources therefore constitute political instruments to compensate for the lack of internalisation of external costs and for competitive disadvantages in distorted energy markets" (Turmes, 2008, p. 19), and also "…the need to internalise all external costs of electricity until fair competition has been achieved." (Turmes, 2008, p. 20). While such arguments are valuable, they need to be extended and fine-tuned for attaining the desired policy goals.

First, the point is not to provide a small RES-E playground in the electricity systems by assigning some support "until fair competition has been achieved." The present assessment of the non-measurable externalities and risks of carbon emissions and of atomic power necessitates the full phasing-out of the bulk application of fossil fuels and of atomic energy. Or, as stated in §1.3 above, the task is phasing-in RES-E while phasing-out NSE. The time for unfair competition against RES-E is over, and there is no time left for "fair" competition between RES-E and NSE if ever this could be defined and organized given the imbalance of power. Therefore the main policy question remains: what are suitable policy instruments for organizing the double phasing processes?

For an example, Germany in 1990 started feed-in support argued as compensation for missing taxes on brown power supplies. In 2000 however, the crucial argument was added that support for RES-E technologies represented a long-term commitment to bring down the costs of such sources. The goal was the creation of a whole new industry (replacing industries expected to decline), with new employment and new exports. It would also enhance energy security at a time when geopolitical struggles over energy represented an increasing threat. Finally, it would in the long-run lower costs of energy supply (§1, Renewable Energy Sources Act, 2004). Here a vision on transition is apparent.

Second, the approach generally recommended (because of its assumed theoretical supremacy) is to charge the externalities and risks of NSE with Pigou levies. Fouquet and Johansson (2008) conclude their article by stating that

> As the costs of RE systems are coming down the learning curve, and if subsidies to conventional energies (fossil fuels and nuclear) are further reduced, external costs of different energy sources reflected in market conditions, any specific support system can be phased out. Those mechanisms which lead to this goal most rapidly should be preferred (Fouquet and Johansson, 2008, p. 4091).

This sounds great, but it may entail perverse effects for the transition process, due to huge rents and excess profits allowed by applying uniform mechanisms and rules on diverse realities (Verbruggen, 2009).[10] The above analysis underlines the necessity to recognize RES-E diversity for preventing excessive profit cashing by inferior types. Fig. 8 shows a uniformly levied electricity price resulting from taxation imposed to internalise

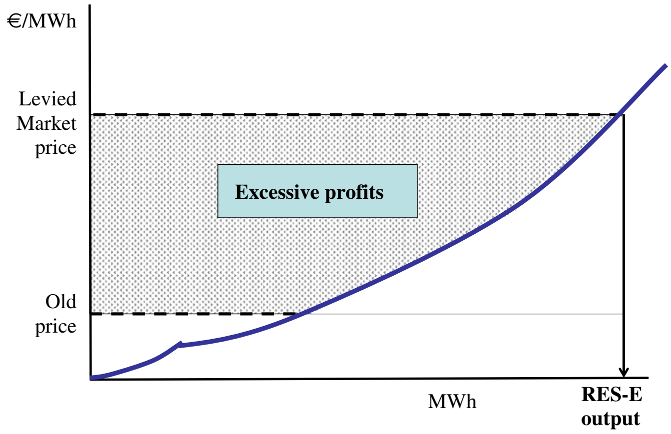

Fig. 8. High levies on brown power create excessive profits in amalgamated RES-E markets.

[9] Particularly if they are exclusive of other support schemes. In Italy and Flanders, a feed-in tariff exists for solar PV; in the UK such a tariff is currently planned.

[10] Fig. 3 in Klessmann et al. (2007, p. 6) also shows the "producer surpluses arising from technology neutral GO trade". They show the present power price at about €55/MWh outcompeting RES-E from the market. By GO the RES-E remuneration would be increased uniformly to €125/MWh, giving rise to significant surpluses (excess profits). Similar excess profits would be caused when NSE prices are raised through Pigou levies to the €125/MWh level.

the externalities of NSE production. Uniformly taxing externalities exerts similar effects as uniformly applied REC prices. To make the transition affordable one needs fine-tuned support doses for growing RES-E shares while charging the expenses of the transition on shrinking NSE shares in the power systems.

Third, during the phasing-in RES-E/phasing-out NSE process the charges due to supporting more RES-E projects that have to be covered by grid electricity consumers will shift. On the one hand, by technological learning the unit costs of generating RES-E by a particular technology will come down. In the long-term, RES-E is likely to become cheaper than current NSE, particularly than newly built NSE. A report for Germany estimates conservatively that total investment in RES-E under the Renewable Energy Sources Act will bring a payback from 2026 onwards, amortizing within a few decades the extra cost of the FIT incurred by then (Wenzel and Nitsch, 2008).

On the other hand, increasing the ratio of RES-E to NSE operates in the other direction. More novel RES-E sources and technologies will have to be developed, and the integration of more and more RES-E capacities in the power systems will bring higher expenses for the dwindling quantities of NSE generation[11] in delivering supplementary and back-up power for variable, stochastic and intermittent supplies. This brings back the contentious issues on priority access to the grids and on pricing power transfers (surplus, back-up and make-up power flows) between independent generators and the grid. FIT systems provide here the right answers for the short and medium term, but one has to prepare for the longer term when tilting nodes in the phase-in/phase-out transition are to be crossed.

7. Conclusion

Our analysis is embedded in a full transition of power generation in the EU to a highly energy efficient, almost exclusively renewable energy dependent activity by 2050. This implies phasing-in renewable production parallel with phasing-out non-sustainable sources such as large fossil and nuclear fission technologies. It provides a more relative significance to renewable energy target setting as a percent of total electricity consumption. It also forces one to think thoroughly about the development and regulation of EU-wide green power markets in the long-run. The EU Commission's 2008 proposal to extend the present flawed green certificates experiments after 2010 was about the worst possible suggestion.

Effective and efficient renewable energy policies are based on an extensive and balanced qualification of the diverse renewable sources and technologies, taking into account all relevant variables, including size and ownership. The success of the German FIT system is mainly a result of having made a good start on such qualification. With the help of graphs we highlight the importance of the qualification and show how FIT systems and quota systems with uniform certificates can handle this. The effects on excess profits (also called rents, producer surplus, windfall profits, etc.) are demonstrated. Equally important are the consequences for inducing technological innovation and enhancing technological diversity.

Although the perspective of the full transition by 2050 frames our analysis, it is still limited to mid-range policy making. The epilogue section mentions a few issues to be addressed in a longer term policy design, for example cautioning against the conventional wisdoms that high Pigou taxing of negative externalities could by itself assure the transition process. The devil is in the details, and will stay there forever.

[11] One may expect that generation of NSE will fall faster and more than capacities installed and operated, leading to smaller load factors, also causing higher unit costs of the kWh they deliver.

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