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Article

Residual Mix Calculation at the Heart of Reliable Electricity Disclosure in Europe—A Case Study on the Effect of the RE-DISS Project

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Abstract: In the EU, electricity suppliers are obliged to disclose to their customers the energy origin and environmental impacts of sold electricity. To this end, guarantees of origin (GOs) are used to explicitly track electricity generation attributes to individual electricity consumers. When part of a reliable electricity disclosure system, GOs deliver an important means for consumers to participate in the support of renewable power. In order to be considered reliable, GOs require the support of an implicit disclosure system, a residual mix, which prevents once explicitly tracked attributes from being double counted in a default energy mix. This article outlines the key problems in implicit electricity disclosure: (1) uncorrected generation statistics used for implicit disclosure; (2) contract-based tracking; (3) uncoordinated calculation within Europe; (4) overlapping regions for implicit disclosure; (5) active GOs. The improvements achieved during the RE-DISS project (04/2010-10/2012) with regard to these problems have reduced the total implicit disclosure error by 168 TWh and double counting of renewable generation attributes by 70 TWh, in 16 selected countries. Quantitatively, largest individual improvements were achieved in Norway, Germany and Italy. Within the 16 countries, a total disclosure error of 75 TWh and double counting of renewable generation attributes of 36 TWh still reside after the end of the project on national level. Regarding the residual mix calculation methodology, the article justifies the implementation of a shifted transaction-based method instead of a production year-based method.

Keywords: guarantee of origin; electricity disclosure; residual mix

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1. Introduction

Electricity flows to our houses and businesses from a mix of sources: from all the power stations that are connected to our power system [1]. Hence, in the physical sense, the origin of the energy that lights up our living rooms is just about as traceable as the origin of the dust on our shoes.

Nonetheless, Directive 2009/72/EC, Article 3(9) [2], requires electricity suppliers to disclose in electricity bills and in promotional materials the energy origin of the electricity they are selling. This process is commonly referred to as *electricity disclosure*, which constitutes of both explicit tracking and implicit allocation of electricity generation attributes (Information about the characteristics of the power production which need to be tracked, most importantly the "energy source and technology used for power production, the related CO_2 emissions and radioactive waste produced" [3]) from production to consumption.

In the EU, guarantees of origin (GO) as defined by Article 15 of the Directive 2009/28/EC, are the main mechanism for explicit tracking of electricity generation attributes. As long as not all electricity consumption is explicitly tracked to certain generation attributes, explicit tracking mechanisms always require the support of an implicit disclosure system, a *residual mix*, in order to avoid double counting. This is important, because consumers expect the tracking system to be reliable and their willingness to purchase renewable power can be significantly reduced if the attributes are double counted [4]. Residual mix is the main topic of this article.

This article presents the improvements in the implicit electricity disclosure of 16 (10 were chosen in the analysis due to their participation in the RE-DISS Project (Austria, Belgium, Denmark, Finland, Italy, Luxembourg, The Netherlands, Norway, Sweden and Switzerland) and 6 due to their relevance in terms of the European GO and/or electricity market (France, Germany, Ireland, Portugal, Slovenia and Spain)) selected European countries, achieved during the RE-DISS (Reliable Disclosure Systems in Europe, Berlin, Germany) project (4/2010–10/2012). These improvements are two-fold. First, RE-DISS has helped competent bodies of electricity disclosure in setting up a reliable disclosure system in their countries through a series of workshops, bilateral meetings, tailor-made recommendations and commenting of legal texts. The effect of these actions, and actions taken independently by Competent Bodies during the project, is quantified in Section 4.1, after comparing implicit disclosure errors before (2010) and after (2012) the project in Section 3.2. Second, RE-DISS has generated significant enhancements in the residual mix calculation methodology as developed by the E-Track [5] project. These enhancements, and their effects in the avoidance of double counting, are elaborated in Section 4.2 and later discussed in Section 5.

The article is structured as follows. Section 2.1 explains the importance of reliable electricity disclosure information in today's electricity markets. Sections 2.2 and 2.3 aim at elaborating how the current explicit and implicit (respectively) tracking and disclosure systems work in Europe and what is their role in renewable energy support. Section 3.1 presents five types of implicit disclosure problems discovered in the 16 selected countries before the RE-DISS project, and Section 3.2 describes how these problems have been overcome during the RE-DISS project, highlighting the major advancements. Section 4.1 quantifies the implicit disclosure error avoided due to these improvements. In Section 4.2, the residual mix calculation methodology presented in Section 2.3 is further studied. Also, the major deficiency of the methodology, corrected during the RE-DISS project, is depicted and new improvements are proposed. Section 5, shows what remains to be done in the field of implicit disclosure in the 16 countries as well as discusses the options for the further improvements of the residual mix calculation methodology.

The scientific scope of this study is the reliable implementation of the guarantee of origin and electricity disclosure mechanisms in the 16 selected European countries. Therefore critical assessment of the effects of GOs and disclosure on the RE market is left out of the research; the focus being on how well the mechanisms are operating. Furthermore, the European countries besides the 16 were not included due to restrictions of available data and small relevance to the international GO system.

Since the article focuses on the implementation of the mechanism itself, it also doesn't consider the sustainability of different energy sources. GO is a mechanism of consumer choice and does not in itself promote sustainable energy production and therefore detailed analysis of various fuels (including their Life-Cycle Assessment) is left out of the study.

The accuracy of the analysis is also limited in how well it considers so-called non-Reliable Tracking Systems. The main problem of these systems is the availability of data and therefore some volumes require estimation. Where estimations are used, this is clearly elaborated in the text.

Finally an important limitation regarding the results is that they are calculated at a national level. It is highly likely that problems beyond this analysis exist at individual supplier level, but these could not be assessed in the scope of this study, because data collection was made on a country rather than individual supplier level.

2. Electricity Tracking and Disclosure in Modern Electricity Markets

2.1. The Role of Electricity Disclosure in the Modern Electricity Markets

The cornerstone of a well-functioning internal electricity market is a deliberate choice of a supplier by the consumers. This choice is founded on general commercial aspects such as price, quality and reliability of service, but it also relates to the generation characteristics of the electricity supplied.

As mentioned, through 2009/72/EC, Article 3(9) [2], customers have the right to know the generation attributes of the electricity supplied to them, meaning from which energy source(s) the electricity was generated and what impacts this production had on the environment (CO_2 and radioactive waste generated). A reliable and transparent electricity disclosure system leads to trust in the energy market [6]. Also references [7,8] point out the importance of reliable disclosure information not only for consumers, but for energy companies as well.

Over the past years, energy regulators have put customer empowerment at the heart of their working program [9]. This development is vital, because according to [10,11] customers' trust in the supplier and the disclosure information increases when a governmental body is involved in checking this information. Also the European Commission (EC) has established the Citizens' Energy Forum in 2007 as a new regulatory platform based on the experiences gained in the Florence and Madrid Forums [12]. "The aim of the Forum is the implementation of competitive, energy-efficient and fair retail energy markets for consumers" [12], and this starts from empowered customers.

Trustworthy and well-presented ([6] highlight that because the electricity bills already tend to be confusing and complex, a clear structured, easy to understand disclosure information is essential. The information is most effective when placed on the bill, whereas placed in an attachment or appendix turns out to be less effective [7,11]. However the placing and appearance of disclosure information is not the topic of this article, but rather the reliability of this information) electricity disclosure information empowers the consumer to opt for desired sources of energy production and leads to a shift in the relevance of parameters for a decision to contract a supplier. Based on their survey, [6] see a possible link between transparent disclosure information available and the switching of electricity suppliers by consumers, but stress that this will only happen if the disclosure system is considered reliable and worthy of paying a premium. Consequently, through purchase decisions, customers are in the position to influence the policies, and in particular the energy mix, of suppliers and therefore indirectly also stimulate sustainable electricity production: "The advent of electricity disclosure has the potential to bring in a new era of citizen involvement in determining the national electricity generation mix" [6].

To sum up, the objectives of electricity disclosure are related to an increased market transparency, the consumers' right for information for making informed choices, education of consumers and stimulation of sustainable electricity generation [6,11]. Most importantly regarding this article, it is emphasized that the disclosure information needs to be reliable in order for these objectives to be achieved.

2.2. Guarantees of Origin as the Instrument for Explicit Tracking in Building Reliable Electricity Disclosure

In order to provide consumers with electricity disclosure information, electricity suppliers must be able to track the energy origin of the electricity back to its production. Tracking generally means a methodology for the accounting of generation attributes (energy source and environmental impacts) in the electricity market and their allocation to final consumption of electricity [3]. This is much more difficult than it seems at first glance, because the electricity market itself is complex.

Theoretically, there are three options how tracking could be implemented:

- along the physical flows in the electricity grid;
- along the trading arrangements (contracts) in the electricity market; or
- in a separate accounting mechanism which is independent from the physical flows and from electricity contracts.

Typical criticism towards electricity tracking is driven by the argument that electrons cannot be traced, which is a well-known and acknowledged fact [11]. The electricity flows in the grid are a result of the demand patterns, the grid structure and the operation of power plants. A flow in a certain direction is usually caused by the balance of a large number of electricity contracts, and is influenced by technical constraints or incidents. The flows in the grid follow physical laws rather than market activities and thus can hardly be a good basis for the tracking of attributes [13].

Physical trading of electricity (which excludes purely financial instruments for price hedging) might be a more suitable basis for tracking of attributes, as it represents the market activity of generators, traders, suppliers and consumers of electricity. Such approach probably comes close to the intuitive expectations by end-consumers of how tracking should work. However, liberalized electricity markets usually encompass different types of bilateral trading, power exchanges with spot and futures markets as well as balancing power, and thus may be too complex to be used for tracking purposes [14]. Furthermore, if qualities of electricity, in terms of their generation attributes, would be added to the electricity market, creating differences in the wholesale market price of electricity from different energy sources, this would severely damage the liquidity of the electricity market [13].

Therefore, the tracking of attributes for purposes of disclosure should in principle be separated from physical flows and from electricity contracts [15]. This allows a tailor-made design of the tracking mechanism according to the needs of the disclosure scheme.

The most prominent instrument for tracking the origin of electricity is the guarantee of origin (GO), which was first introduced by the European Commission Directives for renewable energy (2001/77/EC) and cogeneration (2004/8/EC), and has been taken over recently in the new Directives 2009/28/EC [16] and 2012/27/EC [17], respectively. According to Article 15 of 2009/28/EC, the GO is an accurate, reliable and fraud-resistant electronic document, issued by nationally appointed competent body, representing the generation attributes of 1 MWh of electricity production from renewable energy sources. The directive goes on to define that a GO can be transferred independently from the trading arrangements and physical flows of the associated electricity and cancelled (*i.e.*, used) to verify the origin of 1 MWh of electricity consumption for the purpose of electricity disclosure. The GO is now a reasonably standardized instrument, at least for the tracking of electricity from renewable energy sources. It is important to note that a guarantee of origin is an objective accounting instrument which aims at providing objective information and can therefore be used to support consumer choice. It does not in itself guarantee to the consumer that the specific electricity is sustainable or complies with a specific definition of "greenness" or "environmental additionality".

An important part of today's GO system is the European Energy Certification System (EECS) maintained by the Association of Issuing Bodies (AIB) (The AIB is a not for profit umbrella organization of Issuing Bodies of different countries. The AIB aims to ensure "the reliable operation of international energy certificate systems" through a standardized system EECS—The European Energy Certificate System [18]). EECS enables technically harmonized procedures for issuing, transferring and cancelling

GOs [19] as well as international transfers between the AIB member countries through the AIB Hub [20]. There are currently 16 European countries in the AIB [21].

A reliable disclosure scheme has to be based on GOs, which can in some cases be complemented by other Reliable Tracking Systems (RTS) (such as: Homogenous disclosure mixes determined by a competent body for consumers in non-competitive electricity markets, as long as such segments still exist.

- Renewable energy support systems (e.g., German feed-in tariff) which require a defined allocation of the attributes of supported generation to consumers for disclosure purposes, which cannot be implemented reasonably based on GOs. In this case a pro-rata allocation of the attributes to all consumers which are paying for the support system can be the adequate solution;
- Under certain conditions, the contracts concluded by market participants in the physical electricity market (also known as contract-based tracking). The conditions include the central collection and supervision of such tracking data by an appointed competent body.

Such other Reliable Tracking Systems should only be introduced, if they provide added value to the tracking system (in addition to GOs and the residual mix). Furthermore they should be implemented in a reliable and transparent way, thus not endangering the reliability of disclosure information provided to consumers).

GOs feature the traceability of electricity back to its origin without disturbing the electricity market whilst avoiding double counting of electricity generation attributes in disclosure [13]. The E-Track project found out that having a reliable tracking system in place is the general expectation of all involved parties [4]. Reliability is also emphasized by the European Commission Directive: "Member States shall ensure that the same unit of energy from renewable sources is taken into account only once." [22].

When part of a reliable disclosure system, manifold possible effects of GOs have been identified:

- Support for renewable energy production

Producers can financially benefit from selling GOs. The prices on the international market are not public, but according to an estimate by the authors of this article, the price for large hydro power GOs currently ranges between 0.05 and 0.5 Euro/MWh [22]. However prices can be much higher especially for small hydro power and new renewable technologies. The extra revenue, albeit small compared to e.g., governmental renewable energy support schemes, might attract new investments [15].

- Interaction with governmental renewable support schemes

GOs can alleviate the budgetary burden of existing governmental renewable energy support schemes by allocating more of the burden to those willing to pay more. Besides relieving direct monetary load from governments, even more importantly, GOs relieve political burden. If consumers consider that renewable energy is worth a premium, they are encouraging the government to retain its current targets, and perhaps even to increase them, e.g., [15,23]. GOs give a voice to the people in an area traditionally dominated by the government: renewable energy support. It is especially important to involve the public into supporting renewable energy when considering the current problems faced by governments in maintaining their support schemes, e.g., [24–27].

- Supplier differentiation and consumer awareness

The customers choose their supplier based on the energy mix and the willingness to switch is higher when transparency on the market is high [28–30]. Further, the influence on energy behavior and the willingness to save energy are major drivers for having a functioning GO system in place [11,31].

- Harmonized tracking system in the EU

GOs are a harmonized mechanism within the EU and can cope with changes in the physical and market structures of electricity [13]. The international orientation of suppliers is becoming more relevant especially since the implementation of the new Internal Electricity Market Directive 2009/72/EC [2]. The fact that a growing number of countries fulfill the criteria on GOs and have adopted the EECS system opens an international demand and exchange of GOs. EECS-GOs alone currently cover more than 300 TWh of European renewable electricity production (Figure 1), which is impressive also due to the fact that large volumes of renewable electricity production are not eligible for GOs due to renewable energy support mechanisms and not all countries have yet adopted the EECS system.

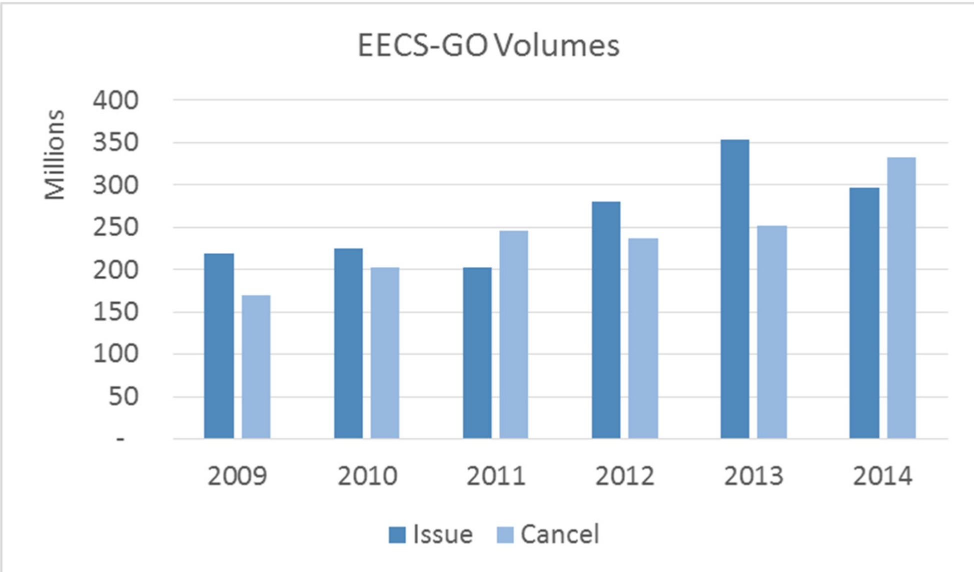

Figure 1. Millions of European Energy Certification System (EECS)-guarantees of origin (GOs) issued and cancelled (used) from 2009–2014 based on [32].

- Enabling operation of labels

According to [33], through the ability to track electricity, GOs enable the reliable operation of electricity labels. These labels use GOs to guarantee the origin of electricity, but add special criteria such as bird-, wildlife or nature conservation, CO_2 reductions, additionality (According to [15], in the context of renewable energy adoption, additionality indicates the additional renewable energy production compared to a Business As Usual case, due to a certain policy or action. For example GOs can deliver additionality, if they increase renewable energy production compared to the situation where no GOs would be issued) *etc.* into the electricity sold to a consumer. Labels can help customers in taking a decision in favor of a specific supplier, as labels are in general easy to understand and aim at a high recognition value.

To sum up, GOs are the mechanism of choice for explicit electricity tracking in the EU and have the potential to bring desired effects into the European electricity system. However, as outlined in Section 2.1, GOs will only be used if electricity disclosure is considered reliable by the consumers, *i.e.*, double counting of generation attributes is avoided [4]. The pronounced rules and guidelines for issuing, transferring and cancelling GOs, especially within the EECS system, efficiently hamper the possibilities for the origin to be tracked twice *explicitly*; but what about consumption not tracked with GOs?

The voluntary characteristic of using explicit tracking instruments is troublesome. Logically, if mostly renewable attributes are explicitly tracked, the remainder of consumption should be less rich in renewables than grid average. One of the most widespread reasons why double counting of renewable attributes still occurs is that competent bodies do not provide a *residual mix*, or do not require its usage for disclosure of consumption which is not explicitly tracked. This may lead to such consumption being disclosed with the production mix of the country where the renewable attributes presented by GOs (and RTSs) are included. The RE-DISS BPR recommend the explicit tracking of all electricity generation attributes, which supports reliable and more meaningful allocation of non-renewable attributes as well. If explicit tracking of electricity were extended to all types of generation attributes, the residual mix would not be required [34] (BPR number 11). (The RE-DISS project has recommended to expand the concept of GOs from electricity from renewable energy and high-efficient cogeneration to all energy sources, in order to support a reliable, explicit allocation of the attributes of any type of power generation [34]. This has already been done in e.g., Austria, Norway, Sweden and Switzerland [35])

The remainder of this article concentrates on the reliability of implicit disclosure, achievable through the correct implementation of the residual mix, because the aims of the GO system can only be achieved where the entire disclosure system is reliable. After all, who would be willing to pay for double counted renewable electricity?

2.3. Residual Mix as the Instrument of Reliable Implicit Electricity Disclosure

Apart from reports of E-TRACK [3,14], and later RE-DISS [36], electricity residual mixes are not well addressed in the academic literature. Raadal *et al*. [37] elaborate the need for a residual mix calculation in an electricity system with explicit tracking, with a focus on Nordic countries. [13] mention that "where default set of attributes is needed a residual mix should be used instead of uncorrected generation statistics in order to minimize multiple counting". This is also a key recommendation of the RE-DISS project [34]. Lastly, [15] has outlined problems in the residual mix calculation methodology, which will be further analyzed in Section 4.2.

Residual mix calculation prevents the double counting of explicitly tracked generation attributes by deducting them from the default mix, which is used for disclosure of non-explicitly tracked consumption. The residual mix is not to be used for any products which are differentiated with regard to the origin of electricity. Its use is restricted to bridging up the difference between the total electricity sales of a supplier and the attributes available from explicit tracking mechanisms where the supplier has not used explicit instruments for the disclosure of its entire sales [34].

The process of residual mix calculation might seem simple, but the international exchange of both electricity and GOs necessitates that also the calculation is coordinated among countries, which adds complexity. In a closed system where no connection to the external world exists, the consumption energy mix of a country equals, in volume and energy sources used, its production mix. But in real life, electricity as well as generation attributes (through GOs) are transferred across borders, which can significantly alter this equilibrium in a country.

The cross-border flow of explicit disclosure information (e.g., in the form of GOs) and of electricity can, at first sight, easily be described as a flow from one specific country to another specific country. One could therefore assume, that in an ideal case, each country should fill in the missing energy origin caused by net export of GOs with the residual mix of the country where the GOs were exported to (Also net physical import of electricity causes a deficit in available generation attributes of a country compared to its consumption, because part of the electricity is coming from abroad. In such case the missing attributes should ideally be derived from the residual mix of the exporting country. In practice however in the case of two European countries, the balancing is made with the European Attribute Mix (EAM), as with the balancing of attributes from GO transactions). In practice, such *bilateral balancing* would be highly complicated considering the international nature of the guarantee of origin markets (including also multiple cross-border transfers) and might likely not even be possible, because of the hen and egg problem: The residual mix of country A depends on that of B, which depends on that of C, which in turn depends on that of A. This might sound manageable with 3 countries, but the calculation needs to be Europe-wide.

One fundamental feature of the RE-DISS residual mix calculation methodology is the concept of a common attribute pool, generally known as the European Attribute Mix (EAM) (Which includes EU27, Norway, Iceland, Switzerland and Croatia but excludes Cyprus and Malta). Instead of different countries interacting with each other, they all interact with this common pool of attributes, which interconnects the domestic residual mixes the same way as the AIB Hub interconnects the explicit tracking of attributes (GOs). This approach does gain a "substitution mix" for the lack of attributes which does not to differentiate between the specific countries of net export of GOs. Although this obviously is a form of simplification of reality, it is consistent within the system borders of a group of countries which apply this approach, and corresponds to the concept of a pan-European internal market not only for electricity, but also for GOs.

The coordinated residual mix calculation for countries within the EAM area is divided into 4 phases (see Figure 2):

1. Data collection from each country:
    a. Net electricity production by tracking attribute including tracked externalities (CO_2 emissions and produced radioactive waste);
    b. Total electricity consumption;
    c. Data on explicitly tracked production attributes (imports, exports and cancellations of GOs and RTSs);
    d. Net electricity import and export *outside* the EAM area. In the case of net import, the residual mix (if exists; otherwise production mix) of the outside EAM country from where the electricity was imported.
2. Determination of the domestic residual mix and surplus/deficit of each country
    a. Determine *available attributes* by deducting exported and cancelled, and adding imported attributes to the generation mix (corrected with physical import or export to outside the EAM area). The mix of available attributes is the *domestic residual mix*;

b. Determine *untracked consumption* by deducting cancelled attributes from total electricity consumption;
c. Compare the volume of the available attributes with the volume of untracked consumption. If the amount of available attributes is greater/less than untracked consumption, the difference is surplus/deficit. The share of attributes in the surplus matches the domestic residual mix.

3. Determination of the European Attribute Mix including tracked externalities
   a. Combine the surpluses from all countries with a surplus.
4. Determination of the final residual mix of each country
   a. In case of surplus, the final residual mix of the country is equal to the domestic residual mix minus the surplus;
   b. Fill the domestic residual mix of deficit countries using the EAM until the volume of available attributes equals untracked consumption.

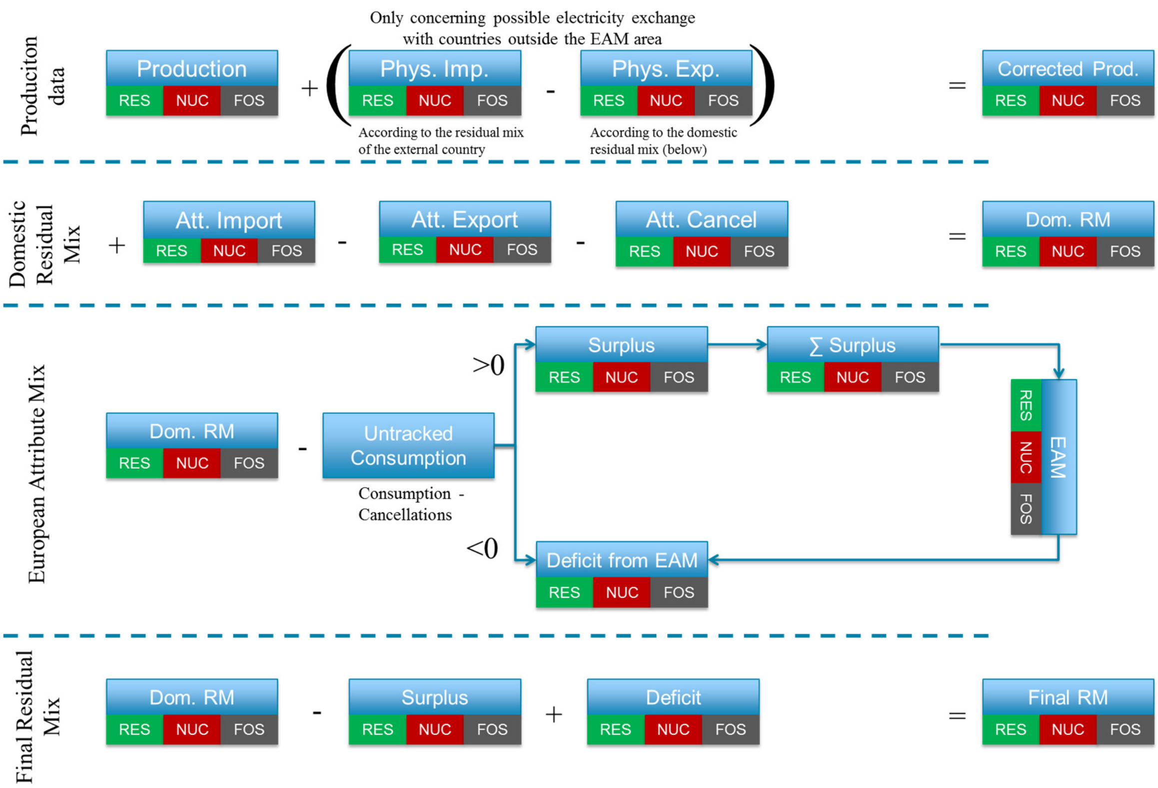

Figure 2. Residual mix calculation process based on [36].

A simplified numerical example of residual mix calculation is presented in Appendix section, Table A1.

Physically, electricity production and consumption in Europe equal each other in volume as long as electricity transfers to and from outside Europe are considered. International trading of GOs and electricity within Europe distort the equilibrium of available generation attributes and electricity consumption volumes on a national level, but on a European level the balance remains. The coordinated residual mix calculation, through EAM, returns this balance at the domestic level. Countries which have a surplus of generation attributes compared to their consumption (typically GO net importers and/or electricity net exporters), give attributes to the common pool and vice versa. Because of the physical balance, the total surplus equals in volume with the total deficit. The coordinated residual mix calculation is a simple yet powerful tool to allow international trading of generation attributes whilst avoiding double counting.

3. Analysis of Implicit Disclosure Problems before (2010) and after (2012) the RE-DISS Project

3.1. Implicit Disclosure Problems in Europe

Based on data collection of the disclosure practices of the 16 selected European countries, the RE-DISS project team found five different types of problems, which lead to double counting in implicit disclosure, due to deficiencies in the residual mix calculation:

- Uncorrected generation statistics used for implicit disclosure;
- Contract-based Tracking;
- Uncoordinated calculation within Europe;
- Overlapping Regions for Implicit Disclosure;
- Active GOs.

The following analysis of errors is based on qualitative and quantitative data collected for the 16 selected countries before (2010) and after (2012) the RE-DISS project.

3.1.1. Uncorrected Generation Statistics Used for Implicit Disclosure

Using uncorrected generation statistics for implicit disclosure appeared to be a straightforward approach followed by several countries, but it leads into the double counting of explicitly tracked attributes (often renewable), as explained in Sections 2.2 and 2.3. On the other hand, the relative shares of attributes which have not been explicitly tracked (particularly fossil and nuclear and their environmental impacts) are underestimated by such an uncorrected mix, because their share would be higher if the tracked attributes had been removed. The relevance of a proper residual mix calculation is best understood by comparing uncorrected generation statistics with residual mixes (Figure 3). The difference between the two is substantial.

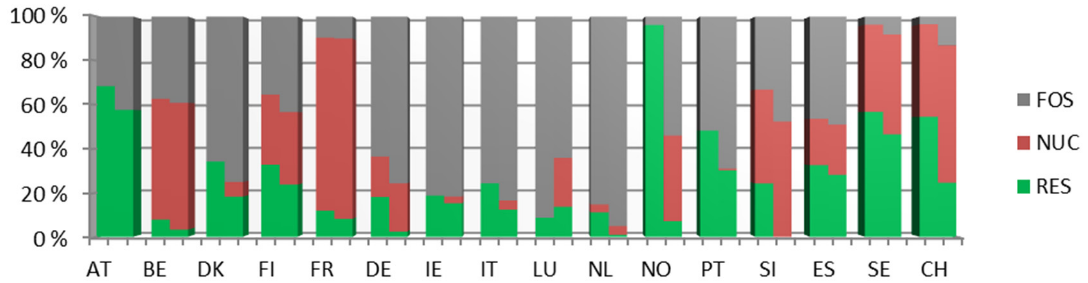

Figure 3. Generation (**left**) and residual (**right**) mixes of 2011 of selected European countries based on [38].

An alternative solution to the problem, without providing a residual mix, is utilized in Austria, Belgium, Germany, Luxembourg and The Netherlands, in which all renewable attributes are deducted from the generation statistics used for implicit disclosure [39]. This easy solution effectively excludes double counting of renewable attributes, but also leads to a disclosure error by neglecting possible remaining renewable shares in the residual mix and thus overestimating the fossil and nuclear shares including environmental impacts.

3.1.2. Contract-Based Tracking

Though in Section 2.2, it was explained that electricity can hardly be tracked along the trading arrangements in the electricity markets, contract-based tracking (CBT) is still allowed to be used for disclosure purposes in some countries. In CBT, the respective volumes which are physically delivered according to grid accounting rules to a supplier and his end-customers are, bilaterally between the buyer and seller, agreed to have been produced by a particular energy source or even a specific plant.

On top of the drawbacks already mentioned in Section 2.2, CBT is mostly not transparent for third parties and thus cannot be deducted from the residual mix of the country (Figure 4). This naturally results in double-counting of contract-based tracked attributes, which often include a higher than grid average share of renewable attributes. In order not to cause double counting, contract-based tracking has to fulfill the specifications for Reliable Tracking Systems as defined by the RE-DISS Best Practice Recommendations (BPR) by e.g., requiring central reporting of all tracked attributes to the national Competent Body, or that such contractual arrangements are accompanied with the transfer and use of GOs [34].

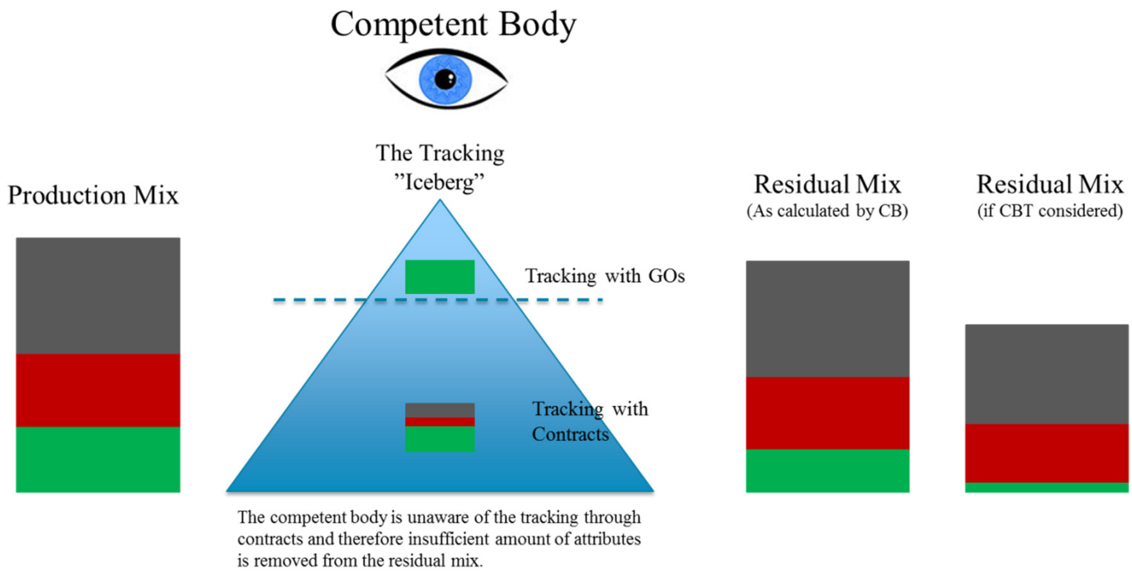

Figure 4. The problem of contract-based tracking as a reliable tracking system.

3.1.3. Uncoordinated Calculation of Residual Mixes within Europe

Uncoordinated calculation of residual mixes within Europe is a particularly relevant problem due to the international trade of both electricity and GOs. As explained in Section 2.3, such international trade means that a country might lack disclosure attributes. Without international coordination and the provision of the European Attribute Mix to balance surpluses and deficits, the deficit countries can either disclose the deficit as *unknown origin*, or expand the domestic residual mix to account for the entire untracked consumption.

For example, before adopting the EAM, Norway included in its residual mix a very high share of unknown origin, because most of the generation attributes were exported through GOs. Yet, given the production mix of Norway, it is likely that consumers presumed this unknown origin as renewable. Extrapolation of the domestic residual mix would have resulted in an even worse solution, because after accounting for the exported GOs the Norwegian domestic residual mix still contained a high share of renewable attributes, as practically all power production in Norway derives from renewable sources. Therefore the deficit would have been fulfilled by a much greener mix (expanding the Norwegian domestic residual mix) than the EAM, leading exported Norwegian GOs to be partially double counted. It should be highlighted that Norway has corrected the problem of unknown origin and currently uses the EAM for the filling up of its residual mix [39].

3.1.4. Overlapping Regions for Implicit Disclosure

The RE-DISS Best Practice Recommendations recommend that a residual mix should by default be calculated on a national level, but under a common decision, several countries can have a mutual residual mix if the electricity markets are closely integrated [34] (Recommendation 28). If some of the involved countries apply a common multi-country mix, and others only their national mix, the disclosure information of the latter countries will be overestimated. Although the problem has been acknowledged for several years, the Nordic countries (Denmark, Finland, Norway and Sweden) have yet to agree on a common solution. Sweden applies the common Nordic residual mix, while Norway and Denmark use their respective national mixes [39]. Finland has in the past unofficially used the common Nordic residual mix, but starting from 2013, the domestic residual mix will be officially applied [39]. This problem is especially relevant if the Nordic residual mix contains a higher renewable share than the Swedish mix, so that Sweden would benefit from such practice, while the other countries' renewable attributes would be double counted without them having a possibility to prevent this. But also in the opposite situation a disclosure error would occur due to loss of renewable attributes and double counting of others. A similar error also exists for countries which apply the overall ENTSO-E mix for all volumes of unknown origin (see Table 1).

3.1.5. Active GOs

Depending on how the residual mix is calculated, the problem of active GOs may occur if GOs issued for electricity production of year X are exported or cancelled after a defined disclosure deadline of the year X. The attributes presented by these GOs may already have been included in the residual mix of year X and thus the subsequent cancellation or export of the GOs would lead to double counting. This area was not well addressed in the residual mix calculation methodology developed by E-Track, but was taken on by RE-DISS and currently the methodology is robust against the active GO problem. The problem will be further discussed in Section 4.2.

3.2. Presence of Implicit Disclosure Problems in Europe before (2010) and after (2012) the RE-DISS Project

The RE-DISS project helped competent bodies of electricity disclosure to resolve problems described in Section 3.1 through consultation and dissemination actions, which led to the spreading of the RE-DISS Best Practice Recommendations for disclosure (BPR). During RE-DISS, seven workshops were carried out that counted with the participation of competent bodies from 16 countries. The first workshops focused on developing the BPR whereas towards the end of the project the emphasis was on supporting implementation. The BPR has been a living document throughout RE-DISS and the competent bodies have actively participated in its improvement.

The RE-DISS team also organized 16 (from Portugal, France, Greece, Latvia, Germany, Slovenia, Romania, Bulgaria, Czech Republic and Iceland) bilateral face-to-face meetings and a number of telephone conferences with competent bodies, performed consultancies of legal texts (for Germany, France, Poland and Iceland) and developed Country Profiles of 22 European countries that included an in-depth analysis of their electricity tracking system and provided tailor-made recommendations.

Through these actions, the RE-DISS project succeeded in triggering important enhancements in the field of electricity disclosure. Table 1 presents the status quo of the five problems in the 16 analyzed countries both before (1) and after (2) RE-DISS. For the sake of clarity it should be highlighted that the improvements listed in Table 1 are due to both efforts of RE-DISS and actions taken independently by the Competent Bodies.

In Table 1 marking X signifies that the problem is fully existing, (X) that it is partially existing and no marking that it is not existing in that country. Furthermore, if no residual mix is calculated in the country (problem 1), problems 3 and 5 are non-applicable. In such cases, the respective cell is marked grey.

4. Results

4.1. Effects from Corrections of Implicit Disclosure Problems during the RE-DISS Project

The effects of the improvements presented in Table 1 are quantified on an overall level in Figure 5 and by country in Figure 6. The results have been derived by simulating (By simulation it is meant that the residual mix of a specific country is calculated according to the national practices of that country. In other words practices, which are known to be unreliable in some cases are simulated and then compared to calculation results according to RE-DISS Best Practices) the implicit disclosure practices of the countries before 2010 (left column) and after 2012 RE-DISS (right column) according to the settings of Table 1. Columns in Figures 5 and 6 indicate volumes of erroneous disclosure compared to a situation where implicit disclosure is implemented according to RE-DISS BPR. Hence a positive column signifies double counting of the corresponding energy source, including externalities, and a negative column that the energy source is under-reflected.

Table 1. Improvements in implicit disclosure during RE-DISS [39].

Country	Problem					Description
	1	2	3	4	5	
Austria (1)	X			X		Before RE-DISS: No residual mix. ENTSO-e mix used for implicit disclosure.
Austria (2)	(X)			X		Improvements: All renewables filtered out of the ENTSO-mix before used for implicit disclosure.
Belgium (1)	(X)					Before RE-DISS: No residual mix. Production mix from which all RES filtered out used for implicit disclosure.
Belgium (2)	(X)					Improvements: No improvements.
Denmark (1)	X	(X)	---		---	Before RE-DISS: No residual mix. CBT for nuclear and fossil.
Denmark (2)						Improvements: Reliable and coordinated residual mix calculation. CBT of nuclear and fossil supervised.
Finland (1)	(X)	X		X		Before RE-DISS: Residual mix of Finland based on the Nordic region. No legal status for residual mix: given as a recommendation by the Association of Energy Industries. Contract based tracking allowed.
Finland (2)		(X)				Improvements: Reliable and coordinated residual mix calculation set by legislation. CBT only for nuclear and fossil.
France (1)	X	X		X		Before RE-DISS: No residual mix. Mix of own production, contracts and ENTSO-e mix used for disclosure.
France (2)	X	X		X		Improvements: No improvements.
Germany (1)	X	X		X		Before RE-DISS: No residual mix. ENTSO-e mix as default value for disclosure. CBT, GOs, RECS and labels used for disclosure.

Table 1. *Cont.*

Country	Problem					Description
	1	2	3	4	5	
Germany (2)	(X)	(X)				Improvements National production mix, from which all renewables filtered out, used for implicit disclosure.
Ireland (1)			X			Before RE-DISS: Disclosure based on contracts and residual mix (residual mix accounts for contracts). Residual mix is not coordinated with other countries.
Ireland (2)						Improvements: Coordinated residual mix calculated.
Italy (1)	X	X	---		---	Before RE-DISS: No residual mix. Disclosure based on fuel mixes.
Italy (2)	X	X	X		(X)	Improvements: Residual mix calculated but not coordinated (deficit disclosed with Eurostat mix). It is not clear whether residual mix accounts for Active GOs.
Luxemburg (1)	---	---		---		Before RE-DISS: No disclosure.
Luxemburg (2)	(X)	X		X		Improvements: Disclosure system implemented. ENTSO-e mix from which all renewables filtered out used for implicit disclosure.
Netherlands (1)	(X)	X	X			Before RE-DISS: Residual mix calculated, but all renewables filtered out. Does not consider contracts and is not coordinated.
Netherland (2)	(X)	(X)	X			Improvements: Residual mix calculation considers contracts and is coordinated, but all renewables are filtered out.
Norway (1)			X		X	Before RE-DISS: Residual mix calculated, but not coordinated. Deficit attributes disclosed as unknown.
Norway (2)						Improvements: Deficit attributes replaced with the European Attribute Mix. Residual mix only accounts for year X certificates.
Portugal (1)	X	X				Before RE-DISS: No residual mix. Disclosure through contracts.
Portugal (2)	X	X				Improvements: Approach to a kind of residual mix.

Table 1. *Cont.*

Country	Problem					Description
	1	2	3	4	5	
Slovenia (1)	X	X		X		Before RE-DISS: No residual mix. Disclosure is based on contracts, GOs and ENTSO-e mix.
Slovenia (2)	X	X		X		Improvements: No improvements.
Spain (1)			X		(X)	Before RE-DISS: Residual mix is calculated, but not coordinated with other countries (domestic attributes expanded if needed). A problem with Active GOs might exist and GOs do not necessarily have to be cancelled in order to be used.
Spain (2)			X		(X)	Improvements: No improvements.
Sweden (1)				X		Before RE-DISS Residual mix based on the Nordic region. Contract based tracking allowed but accounted for.
	(X)	(X)				No legal status for residual mix: given as a recommendation by the Association of Energy Industries.
Sweden (2)				X		Improvements: Contract-based tracking not allowed (disclosure based on GOs or residual mix). Use of the residual mix obligated by law.
Switzerland (1)	X	X				Before RE-DISS No residual mix. Contract-based tracking allowed.
Switzerland (2)	---	(X)		---		Improvements: All electricity explicitly tracked with GOs (no residual mix needed).

The input data in all cases is that collected by RE-DISS for the 2011 residual mix calculation. This depicts that the volume to be disclosed remains constant throughout the analysis and hence that for each country the positive column equals in volume with the negative column, *i.e.*, if renewable attributes are double counted, nuclear and/or fossil attributes are automatically replaced by this amount in disclosure.

Other important settings and framework assumptions for the analysis are as follows:

- Effect of possible other problems besides the five listed have been neglected, e.g., problems relating to explicit tracking;
- in case CBT is allowed in the country, this has been assumed to cover:
    - 50% of untracked (not tracked with GOs or RTSs) domestic renewable production;
    - 20% of untracked domestic nuclear and fossil production;
    - for France (53% of RES and 56% of NUC and FOS) and Sweden (26% of RES, 17% NUC and 0% FOS), country specific estimates have been used.

- In case new legislation is currently being implemented and is scheduled to come into force in the near future, such progress has been taken into account for the after RE-DISS scenario. This is relevant for Germany, Sweden and Switzerland where the law or regulation is already ratified as well as for Finland and Italy where the ratification is in process.

Table 1 indicated that 12 (Austria, Denmark, Finland, Germany, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Sweden, Switzerland) out of the 16 analysed countries made improvements regarding the 5 disclosure problems during the RE-DISS project. In 7 (Denmark, Finland, Germany, Italy, Luxembourg, Norway, Switzerland) of these countries, this significantly reduced the disclosure error as shown in Figure 6. Figure 5 illustrates that on a total level, double counting of renewable attributes decreased by 70 TWh (106−36) and the overall disclosure error by 168 TWh (243−75). Based on [40] these volumes represent 10% of electricity production from renewable energy sources and 7% of electricity consumption, respectively, of these 16 countries. Remaining double counting of renewable attributes after the project amounts to 36 TWh whereas the total disclosure error adds up to 75 TWh. However it should be noted that further errors may reside at individual supplier level as highlighted in Chapter 5.

No unknown origin was disclosed in the after RE-DISS case, compared to 102 TWh in the before case. This is also a significant improvement, because 95 TWh of the unknown origin was disclosed in Norway, where, given the production mix of the country, it is probable that consumers assume a green origin without better knowledge. The decreased amounts of renewable and unknown origin were correctly replaced by nuclear and fossil attributes, for which the negative disclosure error contracted by 58 TWh (76−8) and 110 TWh (134−24), respectively. The decreased disclosure error of fossil and nuclear attributes also increased the amount of disclosed externalities: CO_2 and radioactive waste, but these volumes were not covered by the analysis.

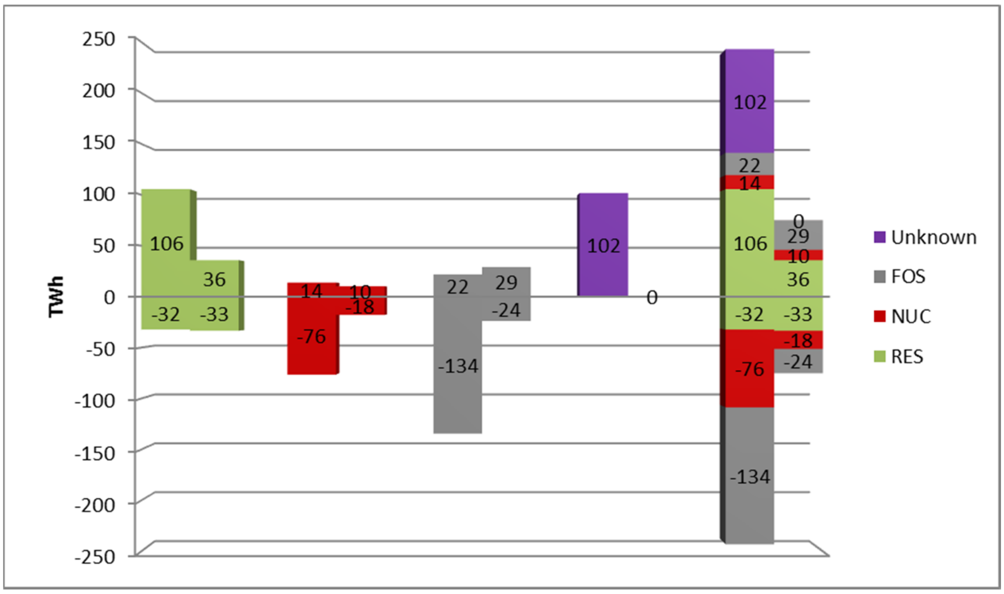

Figure 5. Total quantified implicit disclosure errors per energy source before 2010 (left-hand columns) and after 2012 (right-hand columns) RE-DISS.

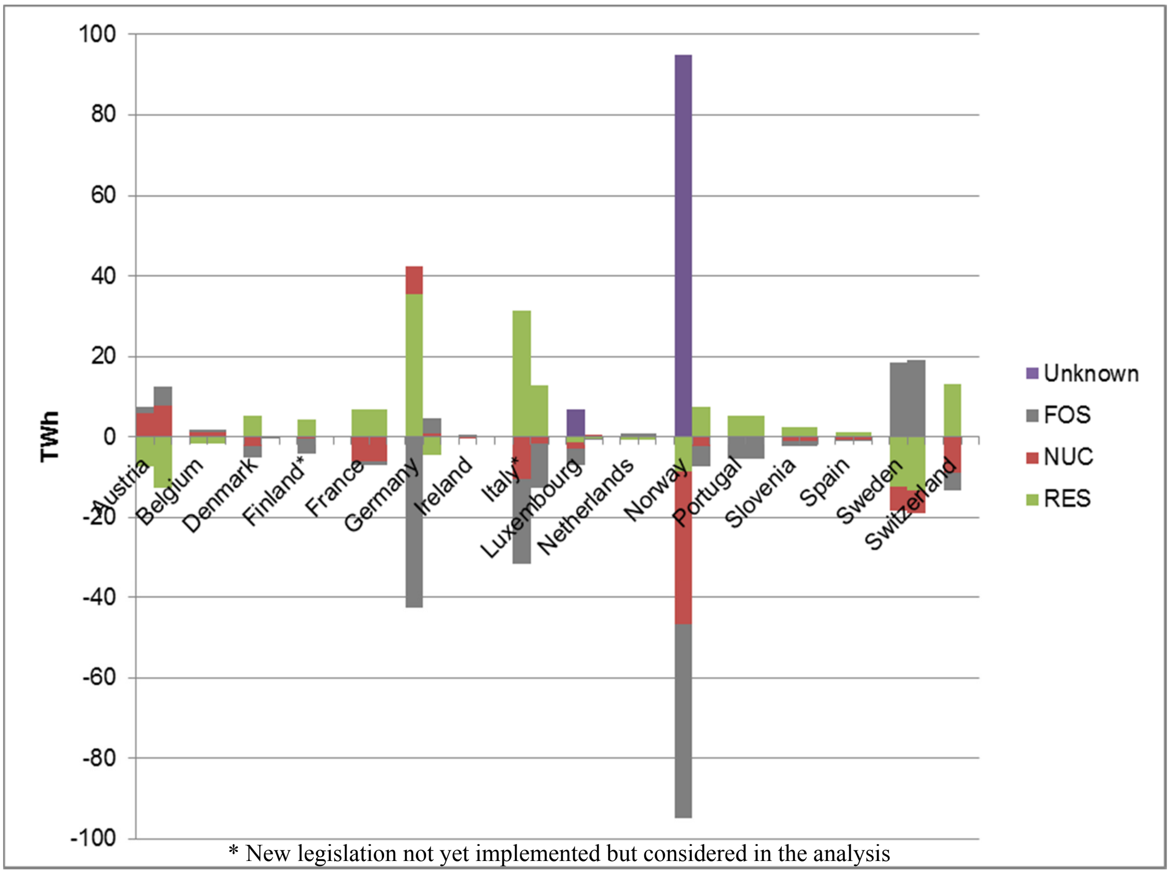

Figure 6. Quantified implicit disclosure errors per energy source and per country before 2010 (left-hand columns) and after 2012 (right-hand columns) RE-DISS.

Out of individual countries, Norway improved its disclosure the most, measured by volume of disclosure error avoided. This resulted from adopting the EAM for fulfilling deficit attributes (problem 3). Germany succeeded in making the largest reduction in double counting of renewable attributes, mostly by enhancements concerning problem 1. Instead of using uncorrected generation statistics, any renewable attributes are now eliminated from implicit disclosure, in Germany. Same amendment was made by Austria and Luxembourg, and was already used by Belgium and The Netherlands before RE-DISS. Although this approach does not eliminate the disclosure error altogether, it is effective against implicit double counting of renewable attributes. Also regarding problem 1, Italy made substantial progress by adopting a residual mix for implicit disclosure. The remainder of the implicit disclosure error in Italy would be avoided by using the EAM.

In Figure 6, the disclosure error is completely corrected in Denmark, Finland, Ireland and Switzerland. Switzerland overcame all problems by forcing all consumption to be explicitly tracked, which removes the need for implicit disclosure. Whereas the other three countries adopted a residual mix according to the RE-DISS BPR (although Finland still has a problem of unmonitored contract-based tracking of nuclear and fossil attributes).

Sweden was one of the top improvers on a qualitative level through the removal of contract-based tracking and adoption of mandatory use of the residual mix where GOs are not used. However in the quantitative analysis, these improvements were out shadowed by the persistence of problem 4: Sweden still uses the Nordic residual mix without a mutual decision between Nordic countries. In the residual mix of 2011, the Nordic residual mix contained a lower renewable share than the Swedish national mix, which meant that renewable attributes were not double counted according to the analysis, but rather under-reflected. This might change from year to year and hence the problem is important.

Throughout the analysis, improvements regarding problems 1 and 3 yielded highest results in the avoidance of disclosure errors and double counting of renewable attributes. However, the impact of developments regarding problem 2, contract-based tracking, was based on an estimated volume, and it is likely that these are in reality as important as those regarding problems 1 and 3. It should also be outlined that the analysis focused on measuring improvements per country, not per problem.

4.2. Improvements to the Residual Mix Calculation Methodology by RE-DISS

Based on data collection of the disclosure practices and quantitative tracking data of European countries, RE-DISS sought improvements to the residual mix calculation methodology. Though pioneering, the major deficiency of the E-TRACK's residual mix calculation model was the lack of detail regarding the time-frame and production year of GO transactions considered in the calculation [15]. Ideally, residual mix calculation of a certain year should reflect transactions of GOs issued for that year electricity production, which can be seen as the intention of the E-TRACK model. However, the 12 months' lifetime of GOs poses a problem for this *production year-based* approach, since not all GOs of production year X are cancelled or expired by the deadline for the disclosure of year X consumption (31st of March year X + 1 according to RE-DISS BPR number 5 [34]). Hence the respective attributes are included in the residual of year X. If in turn the calculation of year X + 1 only considers GOs of production year X + 1, the transactions of production year X GOs after the deadline fall out of the scope of both year calculations. As the case of 2010 depicts, it is crucial to account for the transactions of production year 2009 GOs also after the deadline:

When collecting residual mix calculation data for 2010, the RE-DISS project team observed that GO imports exceeded exports by 32 TWh. Comparison with the AIB statistics indicated that both exports and imports seemed to be missing, but exports in particular. Secondly, the total amount of GO cancellations was suspiciously low in the RM data (174 TWh) given the total cancellation volume during 2010 (211 TWh) [41]. Solving both of these issues was crucial, since according to the residual mix methodology described in Section 2.3, both lacking volume of exports and cancellations in the RM data, lead to production mixes not being corrected with a sufficient amount of explicitly tracked attributes, *i.e.*, implicit double counting.

The difference of imports and exports was a result of two different methods of collecting GO transaction data: Production year-based method (PYBM) and transaction-based method (TBM). The PYBM, used mainly for the Nordic countries, considered the transactions of only production year 2010 GOs that occurred before 31st of March 2011. This, as mentioned, was seen as the original intention of the calculation, but neglected the transactions of production year 2009 GOs which occurred after March 31, 2010. However, the registry systems of some countries were not capable of separating transaction statistics per production year of the GO. This signified that the transaction data for these countries consisted of all GO transactions that occurred during calendar year 2010 (TBM was used), without consideration of the production year of the GOs. The data was clearly inconsistent and neglected a significant volume of especially exports (Figure 7). This was due to the fact that PYBM was used for large exporters and TBM for significant importers and cancellers.

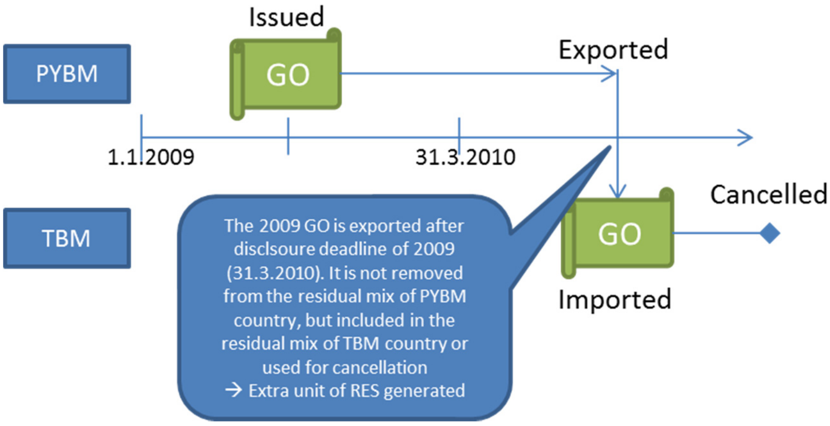

Figure 7. The problem of the production year-based method in residual mix calculation.

Based on detailed analysis of the data, the RE-DISS team was able to correct most of the problem for the 2010 calculation. The analysis also revealed that without corrections, explicit tracking of approximately 48 TWh of renewable and 21 TWh of nuclear attributes would have neglected in the residual mix calculation. For the 2011 calculation, the RE-DISS team set out to find a robust solution for the two major problems of the calculation:

- Transaction data being inconsistent between countries due to use of both PYBM and TBM;
- Active GOs from previous production years causing double counting.

As mentioned, the registry solutions of certain countries were, and still are, incapable of differentiating between production years in GO transaction data. Hence, the only applicable solution for the first problem was to apply TBM for all countries, and neglect the production year of GOs in the transaction data. Crucially, this also solved the problem of transactions of active GOs from previous production years, which were now considered automatically in the residual mix of 2011. In the 2011 calculation the double counting of Active GOs, prevented through TBM, was estimated by RE-DISS to be 40 TWh of renewable and 25 TWh of nuclear attributes.

As a consequence, the TBM, which was previously seen inferior to the PYBM, was lifted as the preferred method for residual mix calculation in RE-DISS. This was due to its ability to deliver a consistent methodology with the available data and to secure the avoidance of double counting in the existing legislative setting, which allows GOs to be usable for 12 months before expiry.

However the weakened accuracy of the residual mix in portraying explicit tracking of the correct production year attributes has stirred up discussions: "The residual mix is used to portray the generation attributes of a calendar year that are not used for explicit tracking… Thus, evidently, the theoretical argumentation to use PYB is better justified, because TB portrays the desired attribute flows poorer" [15]. The discussions have been further fueled by negative renewable volumes occurring in the domestic residual mixes of some countries. This may come about if the leftover of previous production year GOs is significant and if GOs are issued for a large share of the renewable production of the country. Negative renewable balances in final residual mixes of countries can be avoided through transferring the negativity to the European Attribute Mix, but this is not an optimal solution.

To enhance the accuracy of the calculation, the Shifted Transaction-Based Method (STBM) was introduced. STBM considers GO transactions between April 1st X and March 31st X + 1 for year X residual mix calculation, instead of the transactions of the calendar year X. This is logical since the time period to make cancellations for disclosing year X electricity consumption is accordingly shifted from the calendar year. Often most cancellation for year X disclosure occur in February and March of year X + 1, because it is the time suppliers close their electricity product portfolio for year X. The STBM considers this *cancellation peak* (see Figure 8) and the preceding transfer peak correctly in the residual mix of year X, whereas TBM would reflect it in the residual mix of year X + 1.

Figure 8. EECS-GO cancellations in 2012 [41].

A weakness of the Shifted Transaction-Based Method is that, though it decreases the chance for negative renewable balances, by increased accuracy, it does not eliminate the possibility entirely. Furthermore, a significant drawback of all methods that utilize import and export data, is their vulnerability to the GO market conditions. For example, GOs can be stocked in a country which has not yet implemented the expiry rule of GOs or which imposes little or no transaction costs. These patterns have been emphasized in the recent years, and can cause the renewable share in the residual mix to fluctuate significantly from year to year depending on whether the stock is built up or used that year. Even if the fluctuations are not powerful enough to turn the available renewable balance negative in a given year, they are hardly explainable and disturb confidence in the disclosure system. For example, the residual mix of Luxembourg contained a higher renewable share than its production mix in the 2011 calculation [38]. Robustness against market fluctuations is increasingly important due to the future emergence of exchanges in the GO market, e.g., [42].

The STBM was used for the residual mix calculation of 2012, though further solutions have also been considered to address the remaining weaknesses. To address these weaknesses, the Issuance-Based Method (IBM) might be a suitable approach, when certain preconditions are met. This method is presented in Section 5 in principle, but the detailed analysis is out of the scope of this paper.

5. Outlook and Discussion

As outlined, during the RE-DISS project (4/2010–10/2012), 16 selected European countries were able to reduce approximately 70 TWh of double counting of renewable attributes and 168 TWh of total implicit disclosure error. However, this only related to implicit disclosure errors on a national level and it is very likely that even greater errors reside in the individual supplier level. For example, if suppliers do not disclose product related mixes along with the total supplier mix as proposed in RE-DISS BPR number 39 [34], the resulting double counting can be even higher than that found in the analysis of Section 4.1. Therefore, in the future, emphasis should be put on the implementation and supervision of electricity disclosure at the supplier level.

But problems still persist on the national level as well. Out of the 16 countries in the analysis, only Denmark, Ireland and Switzerland had solved all five problems related to implicit disclosure (as well as Austria and Norway after the end of the project as explained in Table 2). Residual mix is still not calculated in France and Slovenia whereas Portugal has only taken initial steps towards a residual mix (problem 1). Likewise, Belgium, Germany and Luxembourg are not calculating a residual mix, but avoid double counting of renewable attributes (same applies partly for the Netherlands).

Contract-based tracking (problem 2) is still an issue in many countries as illustrated in Table 2, but it is better accounted for than in the beginning of the project. Spain and Italy have yet to coordinate their domestic calculation with other European countries (problem 3), whereas Sweden uses a regional approach for its residual mix calculation, which is not agreed upon with other countries in the Nordic region (problem 4). Table 2 presents the remaining steps to be made on a country level in correcting the five problems explained in Section 3.1.

Regarding improvements in the residual mix calculation methodology, RE-DISS solved the issue of double counting concerning Active GOs and introduced the Shifted Transaction-Based Method (STBM). The active GO problem was a result of emphasizing *accuracy* over *reliability* in the residual mix calculation. With RE-DISS coordinating efforts for Best Practices of electricity disclosure, such problems are unlikely in the future. However, it needs to be reminded that an explicit tracking system, requires a *reliable* implicit disclosure system as the backbone of operation. Hence reliability should always be emphasized over accuracy when the implicit system is developed. After all, the primary task of the residual mix is to secure full ownership of renewable attributes to consumers opting for green; not to perfectly portray attributes of correct production year to consumers buying regular electricity.

With this in mind, a future option for residual mix calculation, might be the Issuance-Based Method (IBM), which proposes a new perspective to the calculation. Instead of removing used production attributes (cancelled or net exported), the residual mix would be calculated by deducting attributes of issued guarantees of origin from the production mix and returning unused attributes (expired GOs) into it. The IBM is already correctly used by some competent bodies in the domestic residual mix calculation, but careful consideration is required in order to choose this as an approach for the determination of the EAM.

Table 2. Next steps in improving implicit disclosure on a national level based on [39].

Countries	Recommended Steps for Improving Implicit Disclosure
Austria	In Austria, explicit tracking of all electricity consumption will be required starting from 2013 electricity disclosure. Hence errors in implicit disclosure will be avoided in the future, but this was not covered by this analysis.
Belgium	To increase the accuracy of implicit disclosure, it is recommended that Belgium implement the RE-DISS residual mix, although the current method does not cause double counting of renewable attributes.
Denmark	Denmark has resolved the five problems related to implicit disclosure, presented in Section 3.1.
Finland	It is recommended that Finland ban unmonitored contract-based tracking of nuclear and fossil attributes.
Italy	It is recommended that Italy cooperate with other European countries in forming its residual mix to correctly account for international transfers of electricity and GOs in the residual mix and to prevent double counting of renewable attributes. Furthermore, it needs to be clarified whether the residual mix calculation accounts for previous production year GOs.
Netherlands	It is recommended that The Netherlands cease to filter out the possibly remaining renewable share from the residual mix. This would make the disclosure more accurate although the current form of implicit disclosure does not cause double counting of renewable attributes.
Sweden	It is recommended that Sweden use its domestic residual mix for implicit disclosure instead of the Nordic residual mix, unless Denmark, Finland and Norway also agree to use the Nordic residual mix.
Switzerland	Implicit disclosure is not used as all consumption is explicitly tracked. Hence errors in implicit disclosure are avoided.
Luxemburg	To obtain accurate implicit disclosure, it is recommended that Luxemburg implement the residual mix calculation according to the RE-DISS Best Practices, although the current method of Luxemburg does not cause double counting of renewable attributes.
Norway	Norway resolved the issue of active GOs after the end of the project (but this was not considered in the analysis) and has thus solved the five problems related to implicit disclosure, presented in Section 3.1.
Ireland	Ireland has resolved the five problems related to implicit disclosure, presented in Section 3.1.
France	It is recommended that France implement a residual mix calculation according to the RE-DISS BPR to eliminate implicit double counting of renewable attributes and to achieve more accurate disclosure.
Germany	To obtain accurate implicit disclosure, it is recommended that Germany implement the residual mix calculation according to the RE-DISS BPR, although the current method of Germany does not cause double counting of renewable attributes.
Portugal	It is recommended that Portugal implement a residual mix calculation according to RE-DISS BPR to eliminate implicit double counting of renewable attributes and to achieve more accurate disclosure.
Slovenia	It is recommended that Slovenia implement a residual mix calculation according to RE-DISS BPR to eliminate implicit double counting of renewable attributes and to achieve more accurate disclosure.
Spain	It is recommended that Spain cooperate with other European countries in forming its residual mix to correctly account for international transfer of electricity and GOs in the residual mix and to prevent double counting of renewable attributes. Furthermore, it needs to be clarified whether GOs need to be cancelled before they are used and whether the residual mix calculation accounts for previous production year GOs.

A clear benefit of IBM is that attributes presented by GOs are removed from the production mix of the year of production and country of issue. Hence, it is not affected by peculiarities in the GO market and cannot yield negative renewable balances, because, at maximum, renewable GOs can be issued for the volume of electricity production from renewable sources in the country. GOs of production year X, which are not cancelled by 31st March X + 1, are not without problems for the IBM either, because they disturb the balance between yearly production attributes and consumption to be disclosed. If a large part of GOs is unused before the disclosure deadline, the calculation removes more from the production than consumption side. This means that deficit exceeds surplus in the residual mix calculation and that the EAM should be expanded. Of course, if the volume of active GOs remains constant from year to year, the effect cancels itself out, but this can hardly be relied on.

Expanding of the EAM is not something that should be considered lightly, since the foundation of the coordinated calculation is on the balance of generation attributes and consumption. Therefore, from the perspective of calculating the EAM, the IBM might be a viable option only when implemented in connection with a so-called early expiry solution. The early expiry suggests that year X electricity consumption can only be disclosed with GOs of production year X and hence all remaining production year X GOs should expire at the disclosure deadline of year X. This should in theory not be contradictory to the lifetime of GOs as set by Article 15, paragraph 3 of Directive 2009/28/EC as it states that a GO should be used *within* 12 months of the associated electricity production. However, this is highly debated and countries interpreted the Directive differently in national legislation. Furthermore, to avoid potential arbitrage, all countries should use a harmonized disclosure deadline, which is not currently the case.

Linking the production year of the GO to the consumption year for which it can be used is a logical solution, since electricity consumed in a given year is effectively derived from the energy sources used for electricity production during that year. However, a change of this magnitude into existing procedures on a European level requires wide acceptance from national competent bodies of electricity disclosure and might not be possible without a revision of the EC Directive.

Acknowledgments

The authors of this article would like to thank all competent authorities who participated in the workshops and accepted to endorse the Best Practice Recommendations, which contain the RE-DISS methodology for the calculation of the Residual Mix. Without their involvement and commitment to change national regulations and practices, the RE-DISS work would not have led to the improvements described in this paper.

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Appendix: Numerical Example of Simplified Residual Mix Calculation

In this chapter an example is given on how the residual mix is calculated based on the steps elaborated in Chapter 2.3. This example is to be used together with the process description in Chapter 2.3. For simplification, environmental indicators as well as exchange with countries outside of the European Attribute Mix are not included in the example.

Table A1. Simplified example of residual mix calculation process.

	Country A	Country B	Country C	Country D	SUM		Explanation
1. Data Collection							
1a. Production Mix							
RES	5	10	80	40	135	TWh	
NUC	30	0	40	0	70	TWh	
FOS	40	60	10	20	130	TWh	
1b. Consumption	100	40	140	55	335	TWh	
1c. Certificate Transactions (all RES)							
Imp.	60	30	5	0	95	TWh	
Exp	5	5	60	25	95	TWh	
Canc.	50	15	20	10	95	TWh	
2. Domestic RM							
2a. Available Attributes							
RES	10	20	5	5	40	TWh	1a.Prod+ 1c.Imp-1c.Exp-1c.Canc.
NUC	30	0	40	0	70	TWh	1a.Prod
FOS	40	60	10	20	130	TWh	1a.Prod
SUM	80	80	55	25	240	TWh	
2b. Untracked Consumption	50	25	120	45	240	TWh	1b.Cons-1c.Canc.
2c. Surplus/Deficit							
Surplus	30	55			85	TWh	IF 2a.SumAvailable Attributes >2b. Untracked Consumption—> Surplus = Sum 2a-2b
Deficit			65	20	85	TWh	IF 2a.SumAvailable Attributes <2b. Untracked Consumption—> Deficit = 2b-sum 2a
3. European Attribute Mix							
3a. Surplus to EAM							
RES	3.75	13.75	0	0	17.5	TWh	2c.Surplus*2a.Share of RES in Available Attributes
NUC	11,25	0	0	0	11.25	TWh	2c.Surplus*2a.Share of NUC in Available Attributes
FOS	15	41.25	0	0	56.25	TWh	2c.Surplus*2a.Share of FOS in Available Attributes
SUM	30	55	0	0	85	TWh	

Table A1. *Cont.*

	Country A	Country B	Country C	Country D	SUM		Explanation
4. Final Residual Mixes							
4a. RM of Surplus domain							
RES	6.25	6.25				TWh	2a.Av. Att RES—3a.Surplus RES
NUC	18.75	0				TWh	2a.Av. Att NUC—3a.Surplus NUC
FOS	25	18.75				TWh	2a.Av. Att FOS—3a.Surplus FOS
4b. RM of Deficit domain							
RES			18.38	9.12		TWh	2a.Av. Att. RES + 2c.Deficit*3a.ShareofRESinEAM
NUC			48.60	2.65		TWh	2a.Av. Att. NUC + 2c.Deficit*3a.ShareofNUCinEAM
FOS			53.01	33.24		TWh	2a.Av. Att. FOS + 2c.Deficit*3a.ShareofFOSinEAM
Final RM (%)							
RES	13%	25%	15%	20%			
NUC	38%	0%	41%	6%			
FOS	50%	75%	44%	74%			
Production Mix (comparison)							
RES	7%	14%	62%	67%			
NUC	40%	0%	31%	0%			
FOS	53%	86%	8%	33%			

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Trevino, L. *Liberalization of the Electricity Market in Europe: An overview of the Electricity Technology and the Market Place. Chair Management of Network Industries—MIR*; College of Management of Technology, Ecole Polytechnique Federale de Lausanne: Lausanne, Switzerland, 2008.
2. 2009/72/EC. Directive 2012/27/EC of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EC and Repealing Directives 2004/8/EC and 2006/32/EC. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0055:0093:EN:PDF (accessed on 15 April 2015).
3. Timpe, C.; Seebach, D. Best Practice for the Tracking of Electricity. Recommendations from the E-Track II Project. Deliverable 10 of the IEE Project "A European Tracking System for Electricity—Phase II (E-TRACK II)". Available online: http://www.e-track-project.org/docs/E-TRACK%20II_WP7_Recommendations.pdf (accessed on 15 April 2015).

4. Jansen, J.C.; Seebach, D. Requirements of Electricity End-Users on Tracking of Electricity Generation Attributes and Related Policies. D7 of WP 5 of the E-Track II Project (Final Report). A Report Prepared as Part of the EIE Project "A European Tracking System for Electricity—Phase II (E-Track II)". Available online: http://www.e-track-project.org/docs/final/WP5_D7_Consumer%20requirements%20report_V2.pdf (accessed on 15 April 2015).
5. The E-TRACK Project. Available online: http://www.e-track-project.org (accessed on 17 April 2015).
6. Boardman, B.; Palmer, J. Electricity disclosure: The troubled birth of a new policy. *Energy Policy* **2007**, *35*, 4947–4958.
7. Wilhite, H. An assessment of experiences in the U.S.A. with power and emission disclosure information for energy consumers. Available online: https://www.duo.uio.no/handle/10852/32691 (accessed on 15 April 2015).
8. Markard, J.; Holt, E. Disclosure of electricity products—Lessons learnt from consumer research as guidance for energy policy. *Energy Policy* **2003**, *31*, 1459–1474.
9. CEER 2012. Draft Work Programme 2013 of the Council of European Energy Regulators. Available online: http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/CROSSSECTORAL/2013%20Work%20Programme/CD/C12-WPDC-22–06_WP%202013-PC_18-Jun-12.pdf (accessed on 3 November 2012).
10. Miller, R.D.; Ford, J.M. *Shared Savings in the Residential Market: A Public/Private Partnership for Energy Conservation*; Energy Task Force, Urban Consortium for Technology Initiatives: Baltimore, MD, USA, 1985.
11. Aasen, M.; Westskog, H.; Wilhite, H.; Lindberg, M. The EU electricity disclosure from business perspective—A study from Norway. *Energy Policy* **2010**, *38*, 7921–7928.
12. EC 2013. Homepage of Citizens' Energy Forum of the European Council. Available online: http://ec.europa.eu/energy/gas_electricity/forum_citizen_energy_en.htm (accessed on 30 August 2012).
13. Lise, W.; Timpe, C.; Jansen, J.C.; ten Donkelaar, M. Tracking electricity generation attributes in Europe. *Energy Policy* **2007**, *35*, 5855–5864.
14. Timpe, C. A European Standard for the Tracking of Electricity. Available online: http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/e-track_summary_slides.pdf (accessed on 15 April 2015).
15. Klimscheffskij, M. Tracking of Electricity in the EU—From Directives to Practice. Master Thesis, School of Science, Aalto University, Espoo, Finland, 2011.
16. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en (accessed on 15 April 2015).
17. 2012/27/EC. Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 Concerning Common Rules for the Internal Market in Electricity and Repealing Directive 2003/54/EC. Available online: https://www.energy-community.org/pls/portal/docs/36275.PDF (accessed on 15 April 2015).
18. AIB 2011. Annual Report 2010. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/NEWSEVENTS/Annual_reports (accessed on 15 April 2015).

19. AIB 2013a. EECS Rules. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/EECS/EECS_Rules (accessed on 15 April 2015).
20. AIB 2013b. The AIB Hub. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/FACTS/EECS%20Registries/AIB_Hub (accessed on 11 December 2012).
21. AIB 2013c. AIB Members. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/FACTS/AIB%20Members/AIB%20Members (accessed on 1 August 2012).
22. EEX 2015. Guarantees of Origin—EEX Power Derivatives. Available online: https://www.eex.com/en/market-data/power/derivatives-market/guarantees-of-origin#!/2015/03/19 (accessed on 24 March 2015).
23. Raadal, H.; Dotzauer, E.; Hanssen, O.J.; Kildal, H.P. The interaction between electricity disclosure and tradable green certificates. *Energy Policy* **2012**, *42*, 419–428.
24. Iisd 2012. Trends in investor claims over feed-in tariffs for renewable energy. News article of International Institute for Sustainable Development. Available online: http://www.iisd.org/itn/2012/07/19/trends-in-investor-claims-over-feed-in-tariffs-for-renewable-energy/ (accessed on 1 December 2012).
25. Ref 2011. Turkey implements feed-in tariff, Spain cuts. News article of Renewable Energy Focus. Available online: http://www.renewableenergyfocus.com/view/14994/turkey-implements-feed-in-tariff-spain-cuts/ (accessed on 13 October 2012).
26. Reuters 2010. Czech government adopts a plan to rein in renewables. News article of Reuters. Available online: http://www.reuters.com/article/2010/08/25/us-czech-renewables-idUSTRE67O4DP20100825?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+reuters%2FUSgreenbusinessNews+%28News+%2F+US+%2F+Green+Business%29&utm_content=Google+Reader (accessed on 20 September 2012).
27. Italy cuts FiTs in an effort to balance renewables growth. News article of Renewable Energy Focus. Available online: http://www.renewableenergyfocus.com/view/25145/italy-cuts-fits-in-an-effort-to-balance-renewables-growth/ (accessed on 13 October 2012).
28. Bird, L.; Wüstenhagen, R.; Aabakken, J. A review of international green power markets: Recent experience, trends, and market drivers. *Renew. Sustain. Energy Rev.* **2002**, *6*, 513–536.
29. Hansla, A.; Gamble, A.; Juliusson, A.; Gärling, T. Psychological determinants of attitude towards and willingness to pay for green electricity. *Energy Policy* **2007**, *36*, 768–774.
30. Statistics on switching customers in Austria 2013. Unpublished material.
31. Sogge, C.V.; Øen, J. Klima for Redusert Strøm for Bruk? En Focus Gruppe Studie I Spenningsfeltet Mellom Forbruk Og Miljø, Kunnskap Og Verdier. Master Thesis, University of Life Science, Ås, Norway, 2007.
32. AIB 2015. AIB statistics. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/FACTS/Market%20Information/Statistics (accessed on 20 April 2015).
33. PWC 2009. Green Electricity Making a Difference: An International Survey of Renewable Electricity Labels. Available online: https://www.pwc.dk/da/publikationer/assets/green-electricity-making-a-difference.pdf (accessed on 11 April 2015).

34. RE-DISS 2012a. Best Practice Recommendations for the implementation of Guarantees of Origin and other tracking systems for disclosure in the electricity sector in Europe. Available online: http://reliable-disclosure.org/ (accessed on 15 April 2015).
35. RE-DISS 2012c. Country Profiles. Available online: http://www.reliable-disclosure.org/documents/ (accessed on 15 April 2015).
36. Klimscheffskij, M. Electricity Residual Mix Calculation According to the RE-DISS Project—Methodology of Residual Mix Calculation. Appendix to the RE-DISS Best Practice Recommendations; 2012. Available online: http://reliable-disclosure.org/ (accessed on 15 April 2015).
37. Raadal, H.L.; Nyland, C.A.; Hanssen, O.J. Calculation of residual mixes when accounting for the EECS (European Electricity Certificate System)—The need for a harmonised system. *Energies* **2009**, *2*, 477–489.
38. RE-DISS 2012b. European Residual Mixes 2011. Available online: http://www.reliable-disclosure.org/upload/147-RE-DISS_2011_Residual_Mix_Results_v1_1.pdf (accessed on 15 April 2015).
39. RE-DISS 2012d. *Country-specific Qualitative Data Sheets*; RE-DISS project; European Commission: Brussels, Belgium, 15 October 2012.
40. ENTSO-e 2012. Detailed Monthly Production Data for All Countries for a Specific Range of Time. Excel-Spreadsheet. Available online: https://www.entsoe.eu/data/data-portal/production/ (accessed on 1 May 2012).
41. AIB 2013d. EECS Market Statistics. Association of Issuing Bodies. Available online: http://www.aib-net.org/portal/page/portal/AIB_HOME/FACTS/Market%20Information/Statistics (accessed on 31 October 2012).
42. EEX 2013. Guarantees of origin—Overview. Available online: http://www.eex.com/en/goo (accessed on 17 November 2012).