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Issuance Based Residual Mix Calculation Methodology

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1. Glossary

(Electricity generation/production) Attribute – Attribute refers to a piece of information, which is tracked in order to disclose specific consumption. Most important attributes for disclosure are the energy source and the associated CO2 emissions and radioactive waste. In a de-linked tracking system, the information content of a GO represents all the relevant generation attributes of 1 MWh of electricity.

Available Attributes – Attributes that are not explicitly tracked in order to disclose certain consumption. The pool of yearly available attributes in a country constitutes the domestic residual mix.

Competent Body – Body mandated to supervise reliability of electricity disclosure, typically the National Regulatory Authority.

Electricity Disclosure – The process in which electricity consumers are informed about the energy origin and environmental impact of sold/consumed electricity. Electricity disclosure is set forth by directive 2009/72/EC, Art.3(9) and (EU) 2019/944.

European Attribute Mix (EAM) – The EAM is a calculated pool of surplus available attributes in residual mixes and is needed for reliable coordination of residual mix calculation in Europe. EAM results from surpluses of available attributes compared to untracked consumption in surplus countries. The EAM is used to cover deficits of available attributes compared to untracked consumption in deficit countries.

Explicit Disclosure – Electricity consumption disclosed with explicit electricity tracking instruments such as Guarantees of Origin and Reliable Tracking Systems.

External Countries - Countries outside of the residual mix area. See Residual Mix Area.

Generation – Generation of (physical) electricity.

Guarantee of Origin (GO) – An electricity tracking instrument, defined by Directive 2009/28/EC, Article 15, with the sole purpose of providing electricity disclosure information.

Implicit Disclosure – Electricity consumption disclosed with a statistical mix of generation attributes, e.g. residual mix.

Issuance Based Method (IB) – Residual mix calculation methodology for which the domestic residual mix attribute tracking is primarily done with Issuance and Expiry. See chapter 2.2.

Shifted (Transaction Date) – Shifted dates for data are a way to estimate and compensate the delay between physical electricity activities (generation and consumption) and Attribute activities (Transactions). The shift is one quarter (three months) forward, which means that for RMC of calendar year x the Shifted Transaction Dates are 1.4.x – 31.3.x+1.

Production Date – Generation date of physical electricity for a Guarantee of Origin. See also Transaction Date.

Reliable Tracking Systems (RTS) – RTSs are other explicit tracking systems besides EECS-GOs that are considered reliable and transparent. Typical example of certificate-based RTSs are national GO systems and examples of non-certificate-based RTSs are Feed-in tariffs when linked to disclosure or in some cases contract-based tracking. A Reliable Tracking System guarantees that the attribute of an amount of electricity is not more than once claimed for consumption.

Residual Mix (RM) – The residual mix is a pool of available generation attributes, which are not explicitly tracked through GOs or RTSs. Residual mix is an implicit disclosure mechanism in which volumes and shares of energy sources and environmental impacts of untracked electricity consumption are determined by the statistical mix of a country's yearly generation attributes, available after explicit tracking. It complements the disclosure done with explicit tracking instruments (GOs and RTSs) by determining the origin of the rest of electricity consumption. Residual mix, in line with art.2(13) of the Renewable Energy Directive 2018/2001, is defined on a country level and calculated based on a calendar year.

- **Domestic** – Intermediary residual mix before balancing attributes using common attribute pool. See chapter 3.2 Calculation of the Domestic Residual Mix.
- **Final** – Final residual mix is the final residual mix result of RM calculation. This is the value that is referenced when talking about residual mixes without specifying anything more. Note: the official residual mixes of member states are published by national authorities and the AIB calculated residual mixes are official only when they have been nationally adopted so.

Residual Mix Calculation (RMC) – Residual mix calculation is an implicit tracking mechanism in which shares of energy sources and environmental impacts of untracked consumption are determined by the statistical mix of available attributes.

Residual Mix Area – Residual mix is calculated centrally for a certain area, typically a group of countries or disclosure domains. Exports and imports of both physical energy and tracking instruments are treated differently in the calculation depending on whether they take place inside or crossing the border of the residual mix area. Currently, the Residual mix area is EU28 plus Iceland, Norway, Serbia and Switzerland. The full list of internal countries is: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden and Switzerland.

(Attribute) Transaction – The normal transactions for attributes are: Issuance, Transfer, Cancel and Expiry. The Transfers are further divided to transfers within domain (Transfer) and transfers between domains (Imports and Exports). For Attribute Transactions, both GOs and Reliable Tracking Systems are considered. However, often RTS transactions are more limited and case-by-case analysis is needed on what volumes can be considered as which Transactions for the Residual Mix Calculation.

Transaction Based Method (TB) – Residual mix calculation methodology for which the domestic residual mix attribute tracking is primarily done with Cancellation, Import and Export. See chapter 2.2.

Transaction Date – Date when Attribute Transaction happened. See Production Date.

Total Supplier Mix (TSM) – TSM means the total attributes disclosed in a country; both explicitly tracked and those disclosed through the residual mix.

Untracked Consumption – Untracked consumption refers to consumption that is not disclosed by using explicit tracking mechanisms, such as GOs and Reliable Tracking Systems. Untracked consumption is disclosed with the residual mix.

2. Introduction

2.1 What is Residual Mix?

Residual Mix is the energy source mix that is left over once the reliably tracked consumption is taken out from the generation mix. Residual Mix is used for the purpose that if end-user is sourcing electricity from unknown origin, the energy source mix of it shall be considered as Residual Mix. Residual Mix is an integral part of Guarantee of Origin system for preventing double counting in energy source disclosure.

A Residual Mix is needed when there is a disclosure requirement and when a nontrivial share of the consumption is explicitly tracked using e.g. GOs. Centralized calculation of the Residual Mix is needed if an explicit tracking instrument, for example GO is internationally traded and recognized. Centralized Residual Mixes have been calculated using similar methodology and theoretical framework since 2012, first by EU funded projects E-Track II, RE-DISS and RE-DISS II[1]. AIB took over the calculation in 2015 and renewed the calculation methodology in 2020. In EU wide regulation, the first explicit requirements to calculate and use Residual Mix were introduced the first time in directive (EU) 2018/2001, so called RED II.

2.2 Why Issuance Based Method?

Two methods

The E-Track and RE-DISS projects identified two ways to calculate the Residual Mix: Issuance Based Method (IB) and Transaction Based Method (TB)[2]. Thorough review of these can be found from the RE-DISS II document The Residual Mix and European Attribute Mix Calculation[3].

Transaction Based Method has been the dominantly used method since the end of the RE-DISS II project. There have always been arguments for Issuance Based Method but the most prominent problem there has been the lack of final data at the time of annual calculation. Even though the Issuing Body processes and the data systems behind have improved to a level where many countries issue close-enough final figures within one month of the production, there are still many countries where that is not the case, as will be shown later with the Figure 6, Figure 7 and Figure 8. This document describes a practical approach for Issuance Based Method using available data.

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[1] E-Track II: https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii

RE-DISS I and II: http://reliable-disclosure.org/

[2] In this document Transaction Based Method (TB) is used instead of Shifted Transaction Based Method (STB), but the meaning is the same. This change is done to reflect that also for Issuance Based Method usage of shifted Transaction Date data is proposed.

[3] The Residual Mix and European Attribute Mix Calculation, RE-DISS II, 2015, http://reliable-disclosure.org/upload/234-D7.2_RMCalculation.pdf

When comparing these two methods, it is important to notice that the only differences are in how the reliably tracked attributes (e.g. GOs) are considered. This part is the calculation of the Domestic Residual Mix. The rest of the calculation is fundamentally the same. In Domestic Residual Mix Calculation, TB uses Cancellation, Import and Export volumes to determine tracked consumption whereas IB relies on Issuance and Expiry volumes (Figure 1 and Figure 2). On a system level and over the years, both methods lead to same overall result and as such are evenly justified. On annual and national level, the results of the two methodologies can be different.

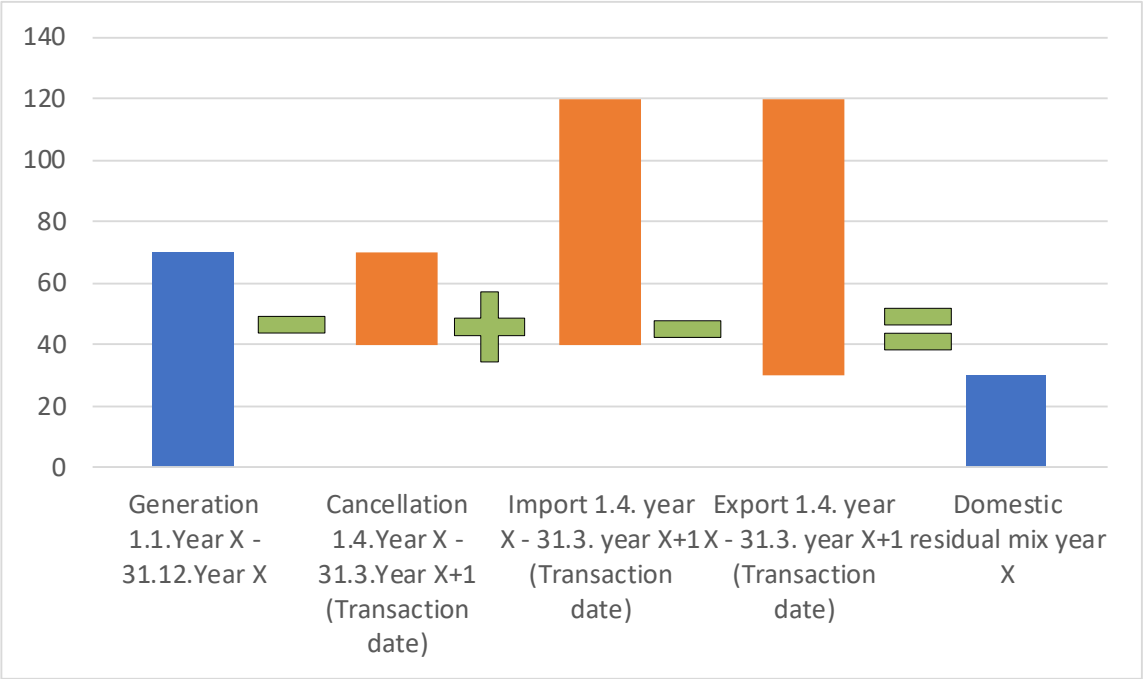


Figure 1: Transaction Based Method for Residual Mix Calculation in a specific country

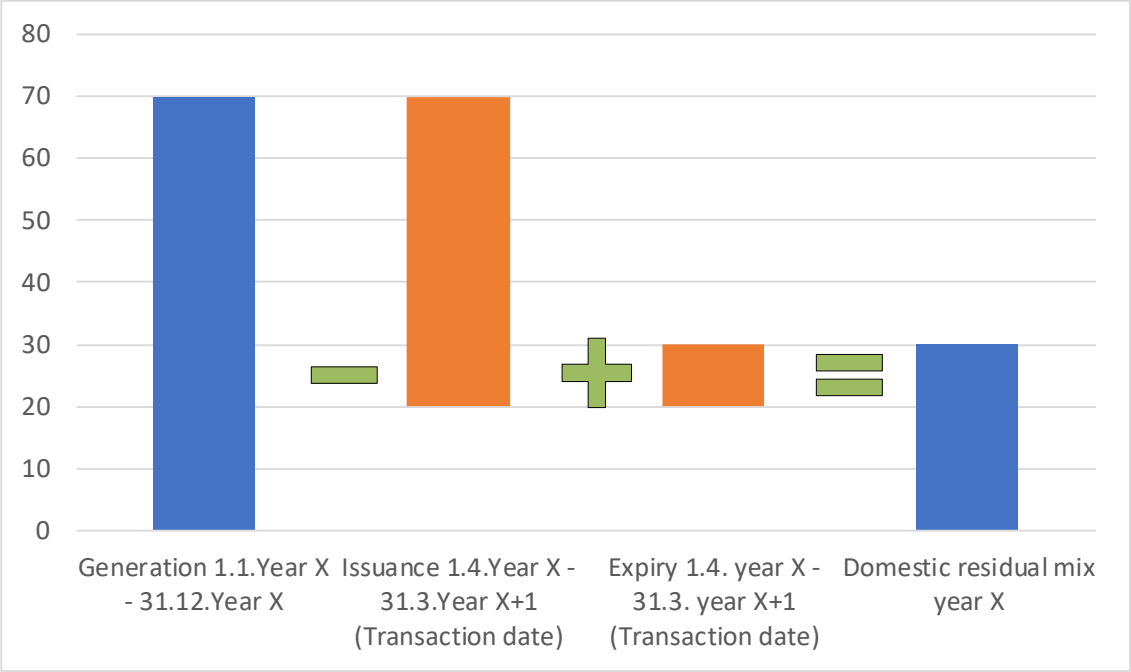


Figure 2: Issuance Based Method for Residual Mix Calculation in a specific country

Nevertheless, both methods integrate all the concepts of Issuance, Cancellations, Imports, Exports and Expiries, although some implicitly. For TB, the Attribute Issuance (and Expiry) exists implicitly through compensating the generation statistics with the Cancellations, Imports and Exports; as none of those would exist without Issuance (or not exist through Expiry).

For IB, the Cancellations are considered for calculating two elements: Volume of Untracked Consumption and Total Supplier Mix (these are identical to TB, but with TB Cancellations are also in Domestic Residual Mix). Untracked Consumption is calculated by subtracting Cancellations from total consumption, which makes sure that the volume of the Final Residual Mix is correct. Secondly for IB, the Attribute balancing is done through European Attribute Mix instead of the Imports and Exports being explicitly considered. This is because when there is an imbalance between Generation, Issuance, Expiry and Untracked Consumption, the imbalance is compensated either by pushing the surplus to the EAM or pulling deficit from the EAM. The additional benefit of this implicit consideration of Imports and Exports is that the trading activities do not exist in this case at all (the importance of this is described in the following paragraphs).

Why leave the TB method behind?

During the last few years the published Residual Mix reports have attracted decent amount of criticism from various sources. One of the main reasons for this has been considered as the increased trading activity between registries. This is because, in the TB, the Imported and Exported Attributes are included in the Residual Mix, as shown in Figure 1. It also shows that when Imports and Exports increase, the effect of Generation and Cancellations to Domestic Residual Mix gets smaller. In other words, if the Import and Export volumes are higher than the Issuance and Cancellation volumes, the trading activities have higher impact to Residual Mix than electricity

generation and consumption. For example, when Imported GOs are reserved to be Exported again, but not yet Exported at the disclosure year end, the trading activities are of exaggerated weight to the TB calculation of the country's Residual Mixes.

When considering how much Import and Export Transactions there are per Issuance and Cancellation Transactions per domain (Figure 3), the result is that for six countries[4] the combined Import and Export volume is higher than the combined Issuance and Cancellation volume. In these cases, trading activities have significant impact to the calculation. For TB Residual Mix Calculation, using Import and Export figures fits the purpose of calculation when those represent net Imports and Exports which lead to actual Cancellations. However, when Imported Attributes are Exported afterwards (and vice versa), those represent mainly noise and market speculation. Furthermore, 15 of the 22 countries has the ratio of more than 0.5, hinting significant impact of trading activities to the Residual Mix.

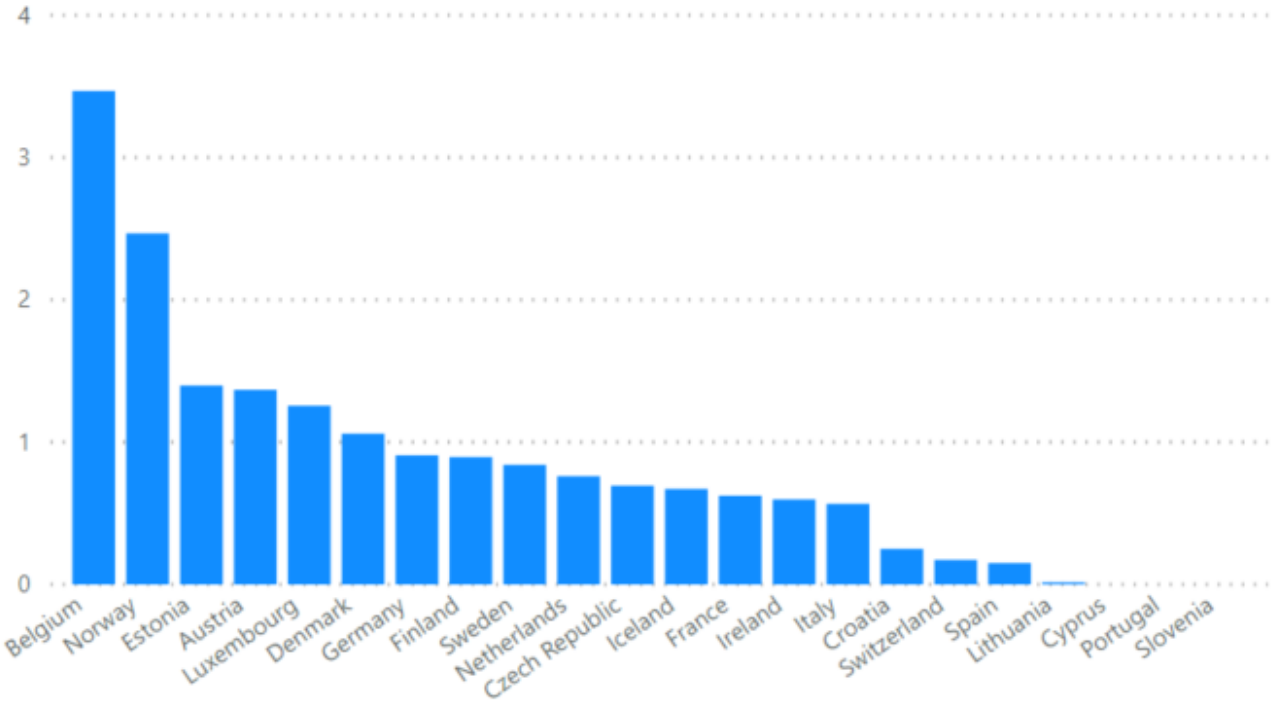


Figure 3: The ratio of Imported and Exported GOs per Issued and Cancelled GOs for 2018 (Shifted-Transaction-date-based volumes).

Other numeric indicators to look at this issue are the comparisons between Export and Issue (Figure 4) and Import and Cancel (Figure 5). The higher the Export volume is compared to Issuance volume the higher the probability of Exported Attributes being originally from some other country. Similarly, if

[4] All Belgian domains are grouped under Belgium because the underlying dataset was connected to the Entso-E statistics where there is only one Belgium.

Import figures are higher than Cancellation figures, not all the Imported Attributes were Cancelled in the country. Nonetheless, in TB all Imports and Exports are equally included irrespective of where the Attributes originated and whether they are followed by Cancellations or further trading activities. With the data available at the moment there is no way to reliably collect the “real” Imports and Exports[5] thus making the uncertainty in TB to high level.

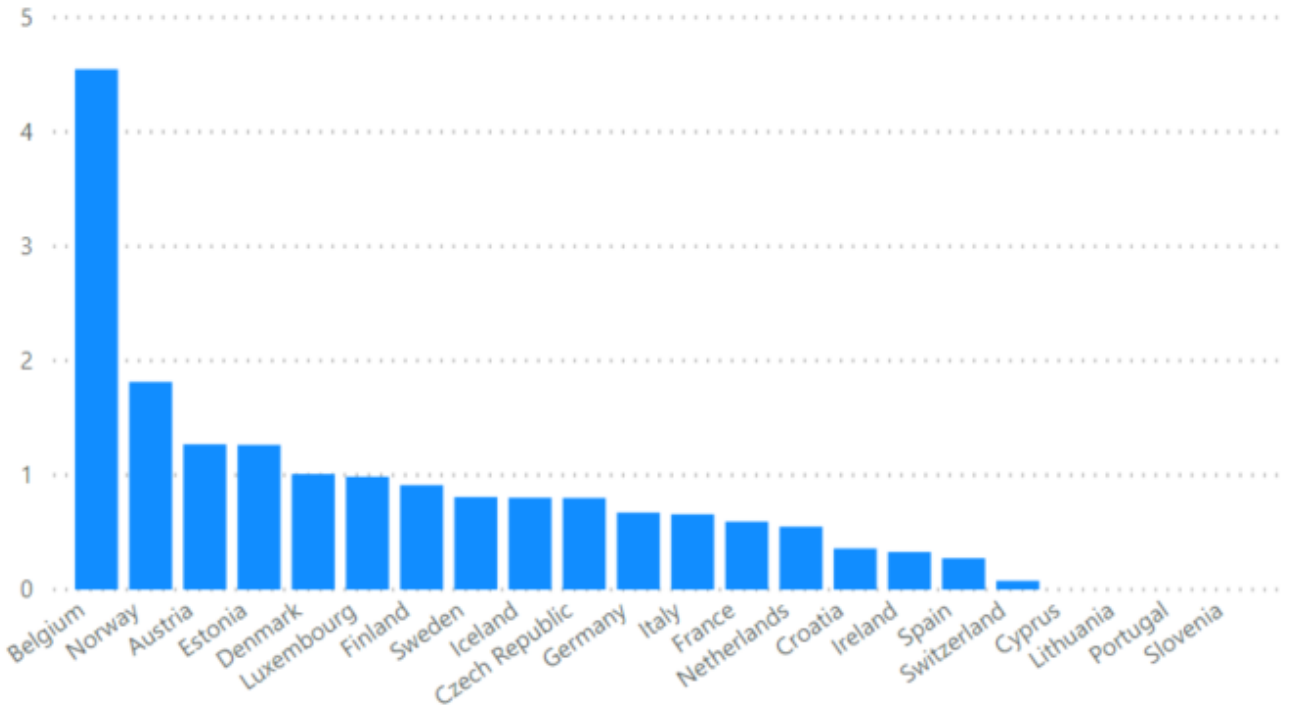


Figure 4: The ratio of Exported GOs per Issued GOs for 2018 (Shifted Transaction Date Based volumes) Note: this does not necessarily mean that the Issued Attributes are Exported: it can be that Imported GOs are Exported again.

[5] “Real” Imports and Exports are considered here as Imports and Exports that only reflect the Cancellations and that where the Issuing country is also known. In other words, Imports and Exports that would fit the purpose of necessary Attribute balancing between countries.

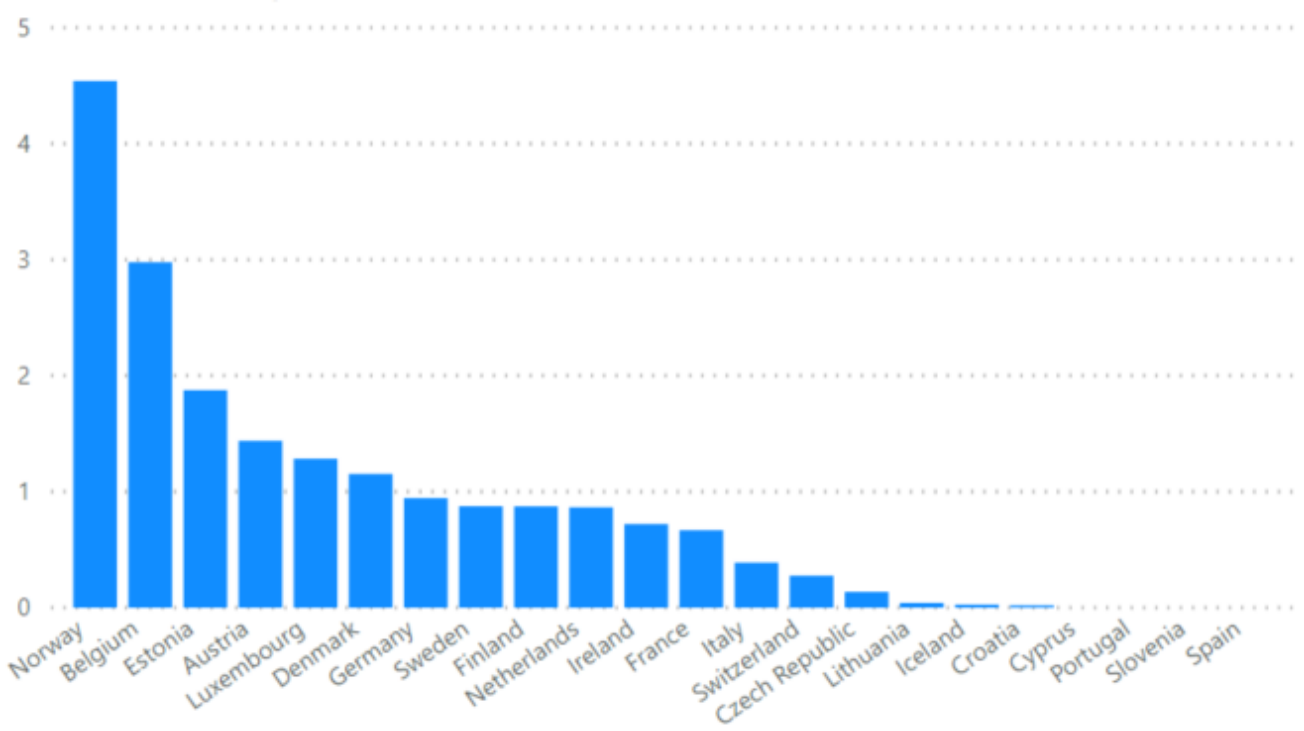


Figure 5: The ratio of Imported GOs per Cancelled GOs for 2018 (Shifted-Transaction-date-based volumes)

Both comparisons indicate that for most of the countries the multiple international transfers of the same Attribute are significant part of all transactions. Another important finding here is that most countries have active trading and it is only a limited number of countries where the international transfers have a little effect.

In conclusion, with the prominence of the trading activities it is very questionable that the Imported and Exported volumes should continue to have direct impact to the Residual Mixes, as they have in the Transaction Based Model.

Pros and cons of the Issuance Based Method

The Issuance Based Method provides a solution for overcoming this problem. In the Issuance Based Method, the Imports and Exports have no direct influence on the Residual Mix. As explained above, IB builds on Issuance, Expiries and Cancellations.

The problem that Issuance Based Method has had, is the problem of getting good data early enough as the Issuance volumes would be Production Date based. This problem is illustrated in the following figures (Figure 6, Figure 7 and Figure 8). In each of the figures, the Production Date based Issuance volumes are compared between the data available at the time of Residual Mix Calculation of that year (2016Q1, 2017Q1 and 2018Q1) and recent data (2019Q2), available a (few) year(s) later. For year 2016, the highest difference is up to thirty million GOs. Over the whole calculation area, the difference to final production volumes would have been ten percentages too low.

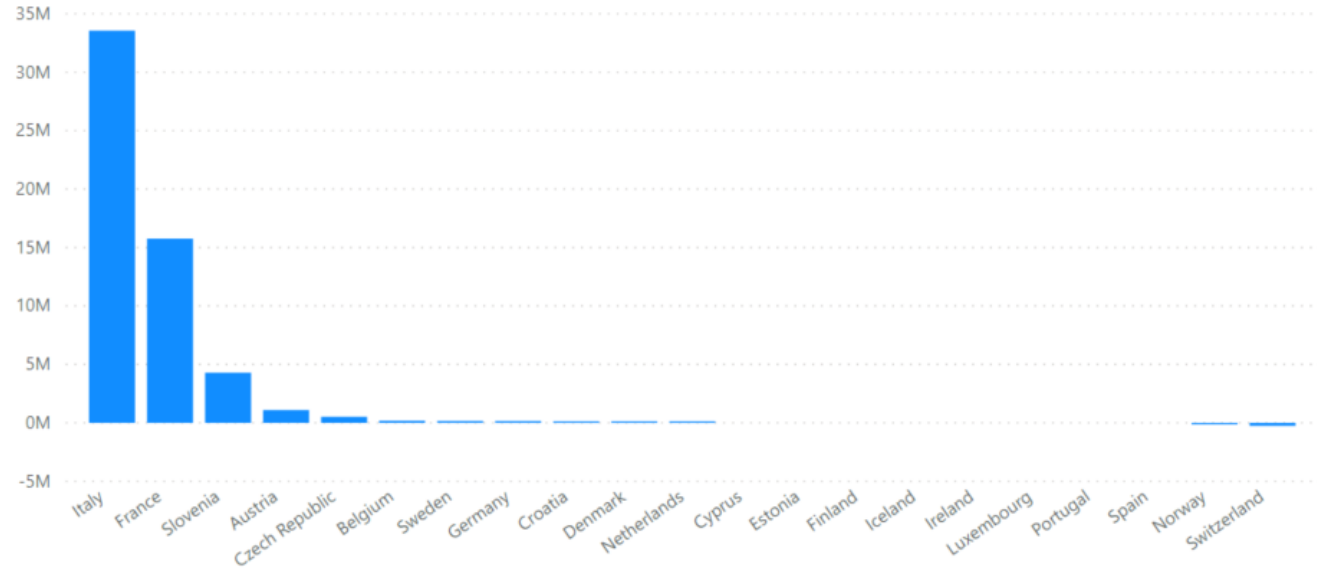


Figure 6: Difference of 2016Q1 and 2019Q2 data for Production Date based Issuance volumes of 2016 (1M = 1 000 000 GOs = 1 TWh)

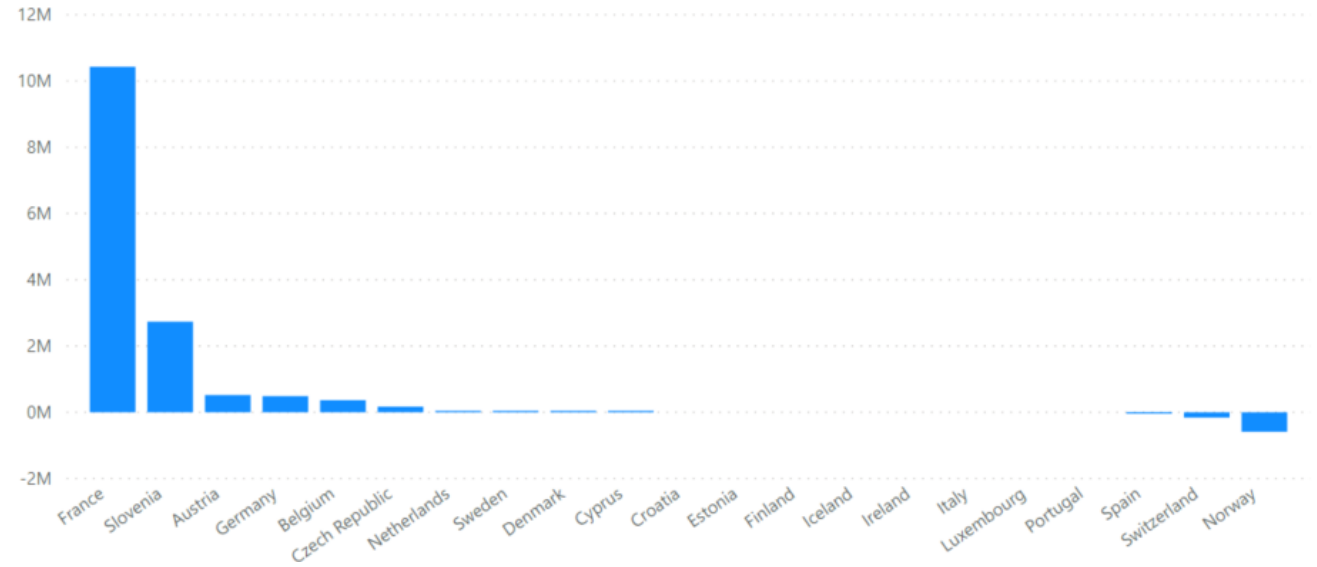


Figure 7: Difference of 2017Q1 and 2019Q2 data for Production Date based Issuance volumes of 2017 (1M = 1 000 000 GOs = 1 TWh)

For the following year, 2017, the gap has narrowed to a ten million GOs at the highest instance. In the last year, 2018, the biggest difference was down to four million GOs. Looking at the trend of last three years the gap has narrowed very progressively and already the situation is quite decent. However, still the differences are several percentages of total productions.

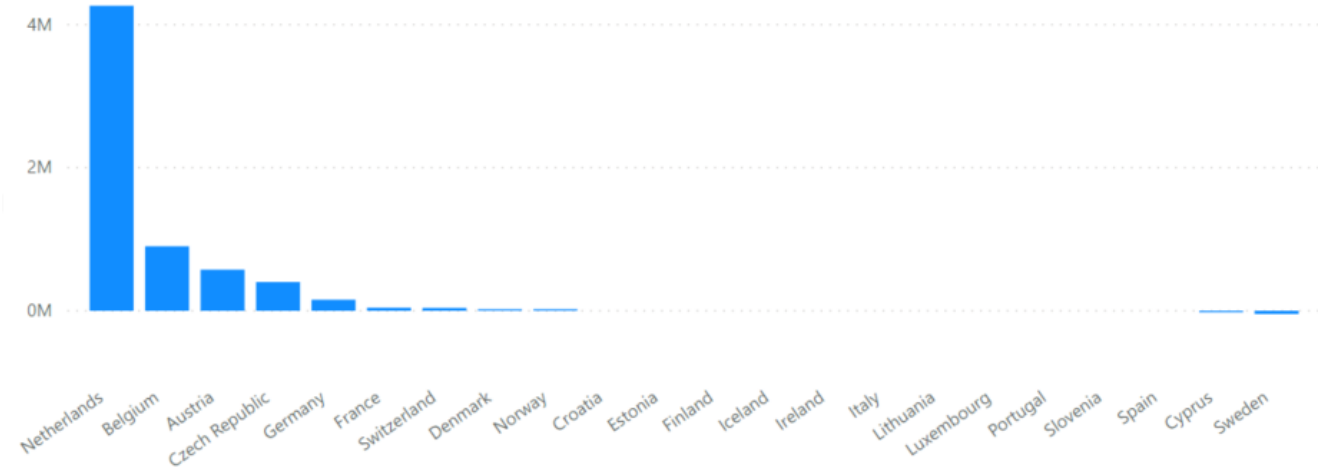


Figure 8: Difference of 2018Q1 and 2019Q2 data for Production Date based Issuance volumes of 2018 (1M = 1 000 000 GOs = 1 TWh)

Furthermore, this phenomenon of incomplete Production-Based data at the calculation moment, is quite complicated for Residual Mix Calculation where the main objective is limiting double disclosure. Late Issuances of GOs would need to be captured in the calculations of following years. For that, first step (with currently available data) would be to compare the new data with the old data of previous year for any differences. Comparing one year backwards contains most of the changes but still older corrections are possible for which the collection of those is rather cumbersome. Nevertheless, otherwise those volumes would be double counted, as those would never be removed from the Residual Mixes.

How to overcome the concern of the late Issuance figures in IB method?

When doing Issuance Based Residual Mix calculation, there is the possibility of using (Shifted) Transaction Date Based Issuance figures. In this document, the Issuance Based Method is proposed with the change to use Shifted Issuance Date[6] figures instead of Production Date Based Issuance figures. The one quarter shift forward is based on the same reasoning than what is used in the (Shifted) Transaction Based method for other transactions: the Attribute activities tend to lack behind the physical world activities, such as after electricity production it takes some time before an Attribute Issuance Transaction happens.

The following Figure 9 shows renewable production volumes compared to the Shifted Issuance Date based volumes. Negative values on this figure could hint that the shift is too far forward, e.g. if production volumes are growing fast enough between years and Issuance happens soon after production. Looking at the negative balances (highlighted cells) here, none of those come from the Shifted Issuance Transactions being ahead of the development of new electricity production. Instead, it is more likely that there is some data discrepancy between AIB GO Issuance statistics and ENTSO-

[6] In other words, Issuance Date is Transaction Date of the Issuing Transaction. Shifted Issuance Dates for Residual Mix Calculation for year x are 1.4.x – 31.3.x+1, just like for all other transactions.

E production figures. For example, in Estonia RES Issuances are year-after-year higher than the ENTSO-E RES production figures, as shown in Figure 10. More likely explanation here is that ENTSO-E figures doesn't include some production or is categorized differently (RES<->FOS).

The negative values in Figure 9 also show the cases where the Negativity balancing of Residual Mix Calculation likely would have needed to be used. For more information about Negative balances, see chapter 3.2.5.

Domain	2016	2017	2018
Austria	33065508	30070248	30875797
Belgium	4203666	3750614	5209833
Croatia	6412302	5245500	5526788
Cyprus	89928	23	-23091
Czech Republic	7776139	5716301	4579791
Denmark	1658891	662645	1014077
Estonia	-11450	-315186	-410103
Finland	4103594	2162331	4770082
France	45690802	50137353	57612547
Germany	163564818	188130766	197065933
Greece	15076010	13903950	16260740
Iceland	2572080	310790	303220
Ireland	5140284	6152604	7563849
Italy	34368671	32704611	18689571
Lithuania	2020000	2352921	1737570
Luxembourg	221185	338379	148194
Netherlands	-327297	1304993	2761719
Norway	8684777	5374583	8669919
Portugal	31073000	21176000	28039000
Serbia	10593450	8970880	10477650
Slovakia	6757470	6583050	5820490
Slovenia	1031671	1340263	2035231
Spain	19005532	7930987	7929927
Sweden	63162735	43338394	36307653
Switzerland	-14809502	3093684	4096477

Figure 9: Production volumes minus the shifted transaction date-based Issuance volumes. Production volumes are from ENTSO-E and Issuance volumes are from AIB.

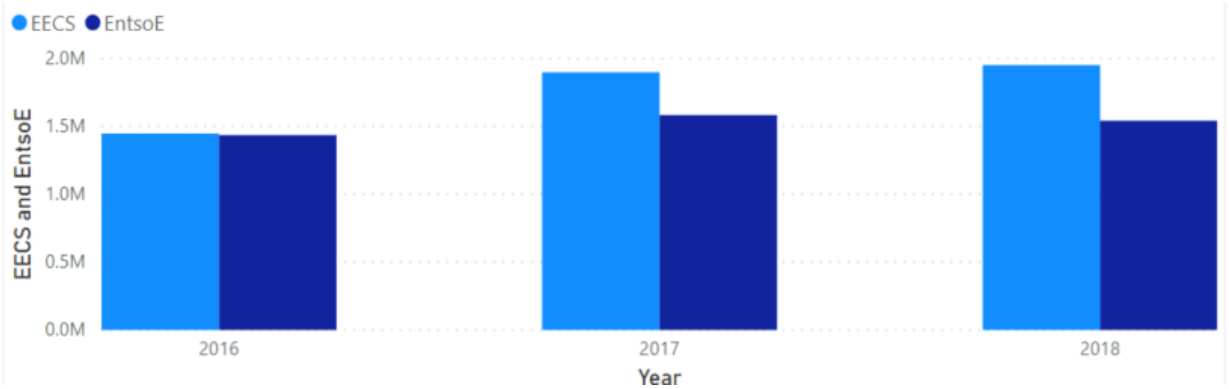


Figure 10: Estonia EECS and ENTSO-E RES

2.3 The calculation differences between IB and TB

Differences between the previous Residual Mix Calculation method (TB) and the new method (IB) described in this document can be listed as:

- With the methodology change to IB, the formula for Domestic Residual Mix is changed from

  $$Corrected\ Generation + Imported\ Attributes - Exported\ Attributes - Cancelled\ Attributes = Domestic\ Residual\ Mix$$

  to

  $$Corrected\ Generation + Expired\ Attributes - Issued\ Attributes = Domestic\ Residual\ Mix$$

  See chapter 3.2 Calculation of the Domestic Residual Mix
- The only environmental indicators to be calculated are direct CO_2 emissions and radioactive waste. See chapters 3.2.4 Environmental Indicators, 3.3.5 Environmental Indicators and 3.4 Total Supplier Mix.
- Consider new source for emission factors or use of common reference values. See chapter 3.1.2 Physical Electricity Production, Consumption, Exchange and Emission Factors
- The change in Domestic Residual Mix formula is also reflected in the formula of domestic Environmental indicators where Imported, Exported and Cancelled Attributes are replaced by the Issued and Expired Attributes. This also means that the EU wide "CO_2 Export Pool"[7] do not need to be calculated anymore. See chapters 3.2.4 Environmental Indicators, 3.3.5 Environmental Indicators and 3.4 Total Supplier Mix.

[7] See The Residual Mix and European Attribute Mix Calculation, RE-DISS II, 2015, chapter 5.4.4 Environmental Indicators

3. Description of the methodology

This chapter draws a lot from the previous methodology document, The Residual Mix and European Attribute Mix Calculation[8], as major parts of the calculation are still the same. For a quick look at the calculation process as a whole, please see Annex A.

3.1 Data Collection

3.1.1 Energy Source breakdown

Data collection and calculation should be performed following the energy source categories listed below. If data is available only at the level of RES/NUC/FOS, the unspecified categories of RES and FOS should be used. This breakdown is the same that has been used in the previous Residual Mix methodology. Further mapping of the ENTSO-E energy sources can be found from Annex B.

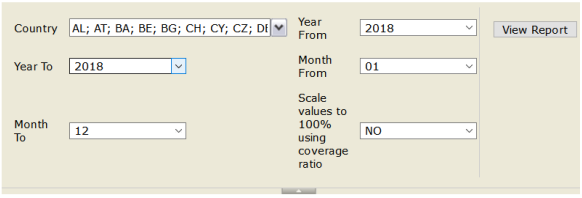
Table 1: Energy Source breakdown

Renewable Unspecified	Nuclear	Fossil Unspecified
Solar		Lignite
Wind		Hard Coal
Hydro&Marine		Gas
Geothermal		Oil
Biomas		

3.1.2 Physical Electricity Production, Consumption, Exchange and Emission Factors

Data on physical energy is acquired from central sources except when a materially better national data source is available on time.

[8] The Residual Mix and European Attribute Mix Calculation, RE-DISS II, 2015, http://reliable-disclosure.org/upload/234-D7.2_RMCalculation.pdf

Data Item	Central Data Source
Country's net electricity production during year X All own consumption (production auxiliaries) of power production is excluded. For hydro plants, this means that only the electricity production relating to natural inflow should be considered. By default, energy ***losses*** related to hydro pumping (and other energy storage) should be considered as consumption and not deducted from production. However, this practice is subject to national regulation, which might require otherwise.	https://www.entsoe.eu/data/power-stats/monthly-domestic/  Note: Entsoe Power Statistics are currently unavailable, and the future is uncertain. This will be updated later.
Country's electricity consumption during year X Grid losses are included as well as losses from pumped hydro (subject to national deviation).	As previous
Net electricity export to and import from External Countries[9] For each country the net exchange of electricity with all relevant External Countries should be determined. In case a country has net import from a specific External country, the net imported volume should be specified by energy source according to the production mix of the External Country (or if available, Residual Mix). In case the country has net export to a specific External Country, the net exported volume is collected as a single value to be used in the calculation. *Important: note that information on electricity transfers between the country and other internal countries* ***should not be*** *collected.*	Download from entsoe.eu, Data → Power statistics, Physical energy and power flows Note: Entsoe Power Statistics are currently unavailable, and the future is uncertain. This will be updated later.

[9] Currently the list of external countries contains all countries outside EU28. As exceptions, Iceland, Norway, Serbia and Switzerland are not external countries. The list of internal countries is: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden and Switzerland

CO2 emissions from fossil-based electricity production in gCO2 per kWh Relates to only direct emissions from electricity production in CO2.	Use existing CO2 country and energy source specific values[10] inherited from RE-DISS II. If a more recent and reliable data source can be identified, it shall be used. Also, if competent bodies report emission data, it shall be used.
Highly active radioactive waste from nuclear electricity production in mg of radioactive waste per kWh	Use existing data inherited from RE-DISS II[11]. If a more recent and reliable data source can be identified, it shall be used. Also, if competent bodies report radioactive waste data, it shall be used.

3.1.3 Explicit Electricity Tracking Information

Explicit tracking information is collected from a mixture of central and national sources.

Data Item	Data Sources
EECS certificates and other certificate-based RTSs[12]: Volumes of Issued, Cancelled and Expired tracking certificates by transaction date in the country during 1.4. year X – 31.3. year X+1 per energy source[13].	EECS certificates: AIB statistics Other tracking instruments: input from Competent Bodies

[10] Treyer and Bauer (2013), Dong Energy A/S, Energi.dk, Vattenfall (2010), Fritsche and Rausch (2009), Bauer (2008) and GEMIS database (GEMIS, 2015)

[11] Compiled from BDEW (2014), DECC (2014), the Platts World Database and IAEA PRIS

[12] Certificate-based RTSs can be for example national GO systems or other tracking certificate systems

[13] According to RE-DISS Best Practice Recommendations [RE-DISS II, 2015] "The deadline for Cancelling GO for purposes of disclosure in a given year X should be 31 March of year X+1". This means that Cancellations which relate to disclosure of year X occur during 1.4.X – 31.3.X+1. To keep the used data in line, the same shifted approach is applied to Issuance and Expiry transactions.

• Note that the dates refer to transactions of all certificates that occur during this time period (not production year X)[14]. • Ex-domain Cancellations from the country, for the benefit of other countries, are not considered in the Cancelling country. • Ex-domain Cancellations for the benefit of the country, from other countries, are considered as Cancellations.	
Non certificate-based RTSs[15]: Explicit tracking per energy source in the country for calendar year X disclosure (e.g. Contract-based tracking, feed-in tariff linked to disclosure) • Explicit tracking by non-certificate-based RTSs are considered as Issued and Cancelled. • Non-certificate-based RTSs between countries, are considered as Issued and Ex-domain Cancelled.	German Feed-in tariff: https://www.erneuerbare-energien.de/EE/Navigation/DE/Home/home.html , Erneuerbare Energien in Zahlen Input from Competent Bodies

3.2 Calculation of the Domestic Residual Mix

3.2.1 Step 1: Determining Available Attributes

Calculation can start after the necessary data as defined in chapter 3.1 boven has been collected. The first step of the calculation is to determine the generation Attributes available after explicit tracking per country. This pool of available Attributes is called the Domestic Residual Mix, and is calculated as follows (also shown in Figure 11):

[14] Considering only production year X attribute transactions would lead to Cancellations, Exports and Imports of GOs from production year X-1 after 31.3.X not to be accounted for in any Residual Mix Calculation.

[15] For example, feed-in tariffs, where supported production is allocated pro-rata to all consumption in the country.

Equation 1: The volume of an energy source in Residual Mix

$$Generation_{Energy\ Source_x} - Issued\ Attributes_{Energy\ Source_x} + Expired\ Attributes_{Energy\ Source_x} = Domestic\ Residual\ Mix_{Energy\ Source_x}$$

Note: Please see the data collection chapter for information on how non-certificate based RTSs should be considered in the above formula.

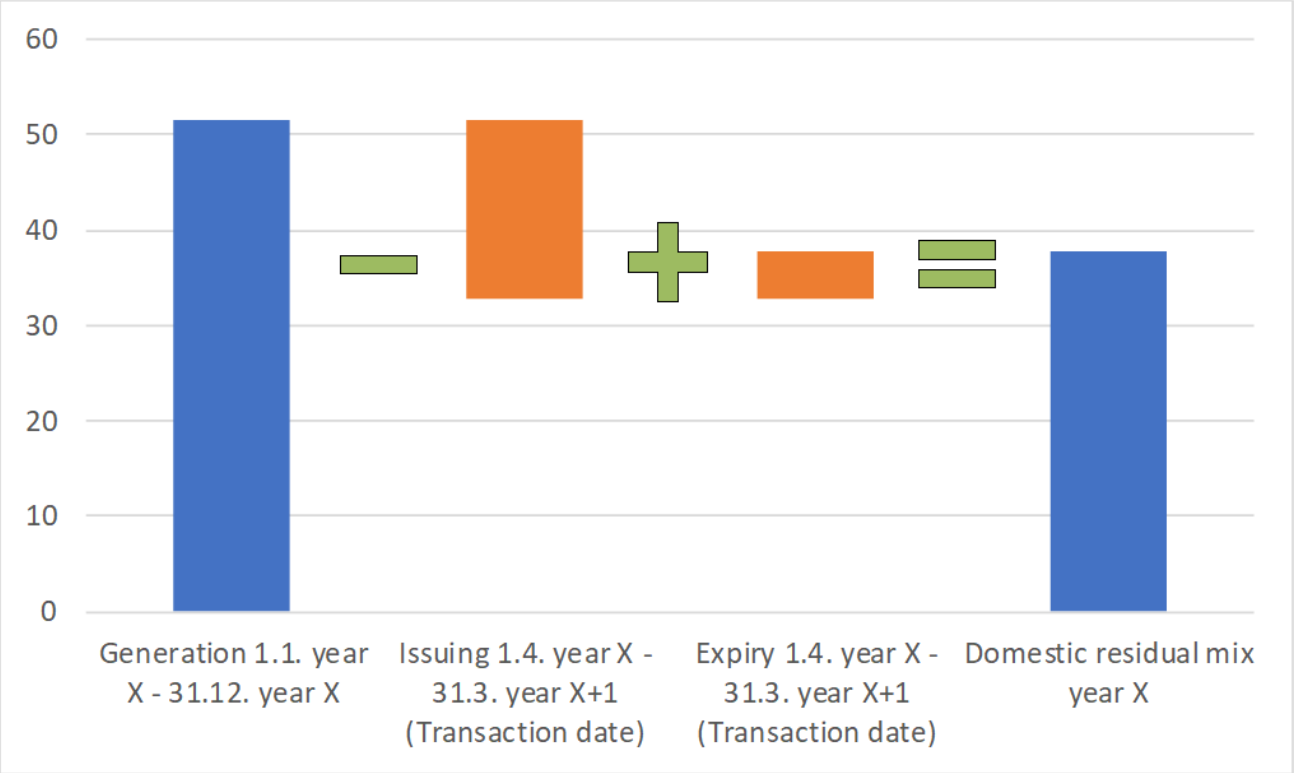


Figure 11: Determining the Domestic Residual Mix

The total volume of the Domestic Residual Mix is calculated as the sum of volumes of different energy sources in the Domestic Residual Mix.

Equation 2: The volume of a Domestic Residual Mix

$$\sum_{x=1}^{n} Domestic\ Residual\ Mix_{Energy\ Source_x} = Domestic\ Residual\ Mix$$

where n is the number of the Energy Sources.

The share of a specific energy source in the Domestic Residual Mix is calculated by dividing the volume of that energy source in the Domestic Residual Mix with the total volume of the Domestic Residual Mix.

Equation 3: The share of Energy Source x in the Domestic Residual Mix

$$\%\ in\ the\ Domestic\ RM_{Energy\ Source_x} = \frac{Domestic\ Residual\ Mix_{Energy\ Source_x}}{Domestic\ Residual\ Mix}$$

Please note: if the country has exchange of physical electricity with External Countries, this is not the final Domestic Residual Mix. Please apply measures of following chapter 3.2.2 to determine the final Domestic RM.

3.2.2 Considering Electricity Imports/Exports with Export Countries

The effect of physical electricity import from or export to External countries on Residual Mix Calculation is elaborated separately here, because it only concerns a small number of countries. In short, net imports are added and next exports are deducted from the nationally available Attributes. If the country has no exchange of electricity with countries outside of the Residual Mix Area, this chapter is not relevant.

- Exchange with External Countries is always considered country by country, so it is possible for an internal country to have both physical electricity net import from one External Country (A) and physical electricity net export to other External Country (B).
- Net electricity import during year X from External Country A is added to the production data of the Importing (internal) country according to the shares of different energy sources in the production mix (or if available, Residual Mix) of the exporting External Country A.
- Net electricity export during year X from an internal country to an External Country B is deducted from the available Attributes of the exporting (internal) country according to the shares of different energy sources in the Domestic Residual Mix of the exporting (internal) country.

Note: Physical electricity import from External Countries should also be reflected in the CO_2 and radioactive waste factors of the country.

The following equation describes how to calculate the content of each Energy source for the Domestic Residual Mix:

Equation 4: The volume of an energy source in Domestic Residual Mix for countries with electricity exchange with External Countries. As defined in the bullet points above, the net imports/exports are calculated individually for each exchange country and for each energy source.

$$\begin{aligned} &Generation_{EnergySource_x} + Physical\ net\ import_{EnergySource_x} \\ &\quad - Physical\ export\ (according\ to\ shares\ of\ the\ preliminary\ domestic\ RM) \\ &\quad + Expired\ Attributes_{EnergySource_x} - Issued\ Attributes_{EnergySource_x} \\ &\quad = Domestic\ Residual\ Mix_{Energy\ Source_x} \end{aligned}$$

After this, the process is as described in chapter 3.2.1 boven (Equation 2: The volume of a Domestic Residual Mix and Equation 3: The share of Energy Source x in the Domestic Residual Mix). The whole process of determining whole Domestic Residual Mix is visualised in the following Figure 12.

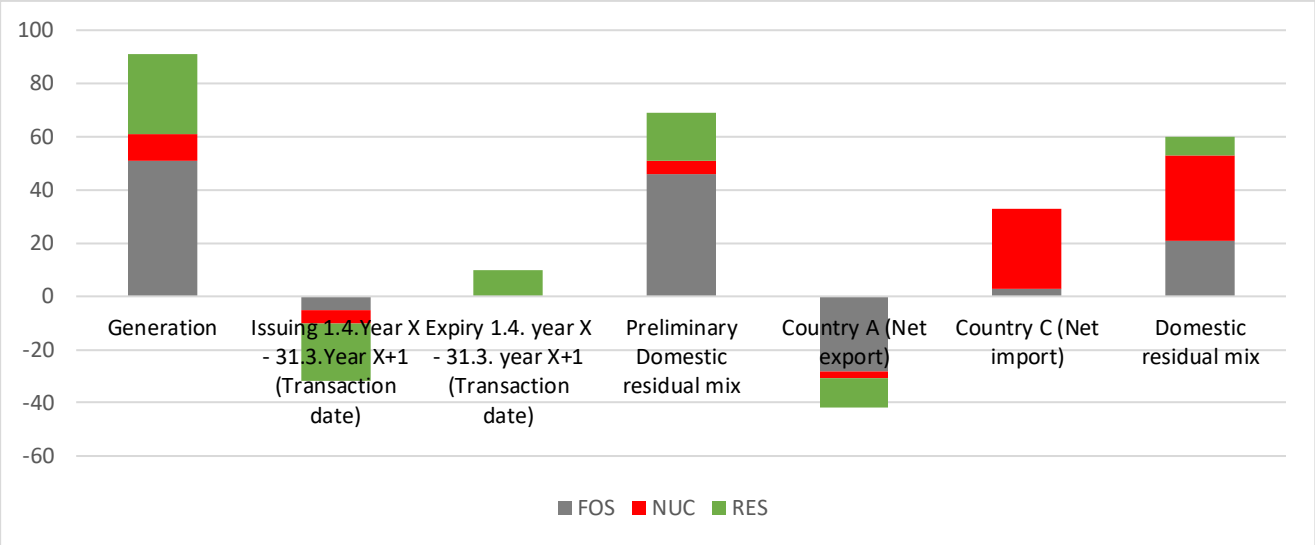


Figure 12: Determining Domestic Residual Mix for countries with electricity exchange across RMC system boundaries. Notice that net export happens with the preliminary Domestic Residual Mix.

3.2.3 Step 2: Establishing Surplus/Deficit

In the second phase of the calculation, the volume of the Domestic Residual Mix as described in 3.2.1 boven is compared with the volume of Untracked Consumption in the country.

Untracked Consumption is such a consumption, which has not been disclosed with explicit tracking instruments. Therefore, it can be obtained simply by deducting all Cancellations (as collected based on 3.1.3 boven) from the country's yearly electricity consumption (Equation 5 and Figure 13).

Equation 5: Volume of an Untracked Consumption

$$Electricity\ consumption - \sum_{x=1}^{n} Cancelled\ attributes_{Energy\ Source_x} = Untracked\ Consumption$$

where n is the number of the energy sources

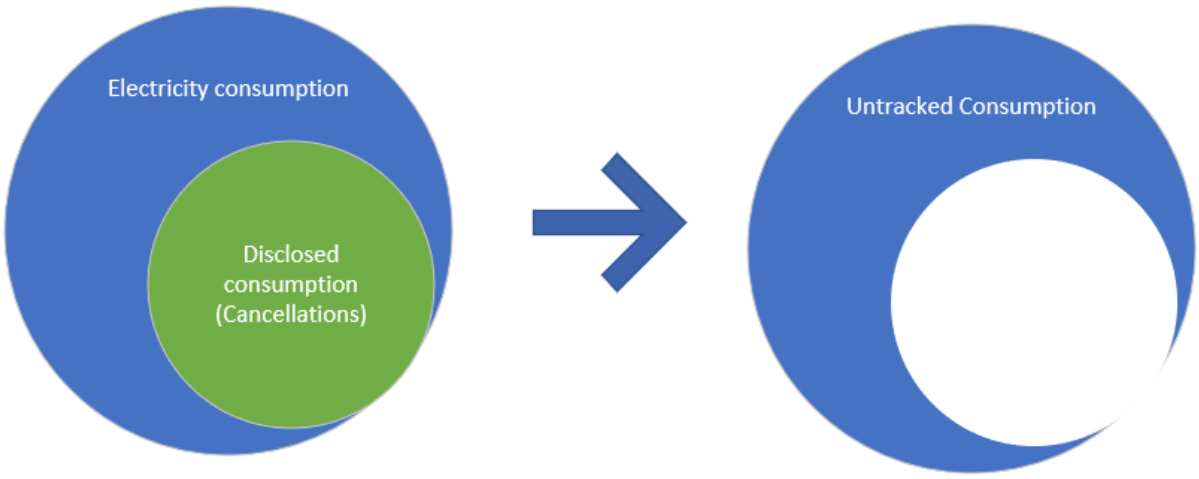


Figure 13: Determining Untracked Consumption out of the total electricity consumption of the country

The difference between the volumes of the Domestic Residual Mix and the Untracked Consumption is the deficit or surplus of Attributes in the country. In case the country has an Attribute surplus, the surplus is collected to the European Attribute Mix. In case the country has an Attribute deficit, the deficit needs to be fulfilled with Attributes from the European Attribute Mix. This will be further explained in chapters 3.3.1 and 3.3.3 respectively.

Equation 6: Determining surplus or deficit of Attributes of a country

$$If\ Domestic\ RM > Untracked\ Consumption \rightarrow Surplus$$

$$Surplus = Domestic\ RM - Untracked\ Consumption$$

$$If\ Domestic\ RM < Untracked\ Consumption \rightarrow Deficit$$

$$Deficit = Untracked\ Consumption - Domestic\ RM$$

3.2.4 Environmental Indicators

Environmental indicators are the CO2 onsite emissions and Radioactive Waste.

The emissions of the Domestic Residual Mix are the emissions of the Production Mix adjusted with the Issued and Expired Attributes except for countries who exchange electricity with External Countries. The CO2/Radioactive Waste factor of the production mix is obtained by multiplying each energy source (after considering physical import/export) in the production mix with the CO2/Radioactive Waste factor of that energy source for that country.

Equation 7: CO2 emissions of Energy Source x in Domestic Residual Mix

$$CO_2\ in\ Domestic\ Residual\ Mix_{Energy\ Source_x} = \left(Generation_{Energy\ Source_x} - Issued\ attributes_{Energy\ Source_x} + Expired\ attributes_{Energy\ Source_x}\right) * CO_2Factor_{EnergySource_x} + Physical\ net\ import_{EnergySource_x Country_y} * CO_2Factor_{EnergySource_x Country_y} - Physical\ net\ export_{EnergySource_x Country_y} * CO_2Factor_{EnergySource_x Country_y}$$

If the emission factors of the External Country are not known the factors of the to be calculated country are used instead.

Equation 8: CO_2 emissions of Domestic Residual Mix

$$\sum_{x=1}^{n} CO_2\ in\ Domestic\ Residual\ Mix_{Energy\ Source_x} = CO_2\ in\ Domestic\ Residual\ Mix$$

where n is the number of the energy sources

Equation 9: CO2 emissions factor of Domestic Residual Mix

$$CO_2\ factor\ of\ Domestic\ Residual\ Mix = \frac{CO_2\ in\ Domestic\ Residual\ Mix}{Domestic\ Residual\ Mix}$$

3.2.5 Negative Balances

Negative Balances happen when Domestic Residual Mix at energy source level is negative. For proper energy mixes (RM and EAM) none of the energy sources can be negative so negative balances must be accounted for in one way or another.

Looking at the Domestic Residual Mix formula at the energy source level (Equation 1) it is evident that for Issuance Based methodology negativity is only possible when more GOs have been issued than the actual electricity production has been. As the collected Issuance volumes are shifted transaction date-based volumes, it is likely that the Issuance volume does not exactly reflect the physical production. If the calculation would use Production date-based Issuance volumes, the negative balances could not exist unless there are errors or incompleteness in the data.

As negativity happens, there needs to be a way to compensate it. Compensation flow as such is similar irrespective of which the calculation methodology is. In the compensation flow for negative Attribute balances three are five levels of compensation as described below:

1. After calculating Domestic Residual Mix (Equation 1) some or all Energy Sources can be negative. The first compensation step of negativity in RES or FOS Attributes is to move the negative balance to RES/FOS Unspecified category.
2. If the RES/FOS Unspecified category is not enough to compensate all negativity, then the next step is to compensate from other RES/FOS categories. This compensation is done with the Domestic Residual Mix shares, where the negative balances of individual Energy Sources is considered as zero for determining the mix to use. The Steps 1 and 2 are the only

compensation which can be done on a national level which means that at this point the Domestic Residual Mix is already final and the remaining negativity is escalated to a higher level.

3. If the other RES/FOS categories of Domestic Residual Mix are not enough, then the negativity is compensated from the preliminary European Attribute Mix. At first this is done by compensating energy source by the respective energy source. This is also the first step where negativity in Nuclear can be compensated. It is compensated from the EAM Nuclear category. *Note: the European Attribute Mix calculation is described in the following chapter 3.3 and its preliminary result is needed for the compensation steps 3.-5. For the EAM calculation, the Domestic Residual Mix reached in step 2 is used.*
4. If the respective energy sources in the preliminary European Attribute Mix are not enough, then the negativity is compensated from the RES/FOS Unspecified categories of the preliminary European Attribute Mix.
5. Similarly to step 2, if the EAM RES/FOS Unspecified categories are not enough then the negativity is compensated from other RES/FOS categories according to the EAM shares. This is the last step where the compensation stays within the Residual Mix Calculation of one year. *Note: After this step final EAM can be calculated.*
6. Finally, if the previous steps are not enough to compensate all negativity then the remainder is moved to the EAM of the following year, which means the negative leftover has to be stored for and included in the Residual Mix Calculation in the next year.

Note that negativity in RES/FOS/NUC categories need to always be compensated from within, so it is not possible to in any case to compensate negative RES from FOS or NUC categories. Up to the RMC 2018 the final step of compensation has not needed to be used yet. A couple of times it has been close but not needed after all.

3.3 European Attribute Mix and Final Residual Mixes

3.3.1 Surplus countries

Domestic Residual Mix Attribute surpluses and deficits were calculated in chapter 3.2.3 Step 2: Establishing Surplus/Deficit. In this chapter it is described how the total Attribute surpluses constitute the European Attribute Mix (EAM).

Countries with Attribute surplus feed Attributes to the EAM according to the shares of energy sources in their Domestic Residual Mix and for the volume of the surplus, as shown in Figure 14 below.

Figure 14: Determining Surplus

For determining Energy Source specific contribution to the EAM, the country level surplus is multiplied with the Domestic Residual Mix shares:

Equation 10: The contribution of Surplus Country n for Energy Source x into the EAM

$$Surplus_{Country_y} * \%\ in\ the\ domestic\ RM_{Energy\ source_x Country_y} = Contribution\ to\ the\ EAM_{Energy\ source_x Country_y}$$

3.3.2 Final Residual Mix in Surplus Countries

For surplus countries, the Final Residual Mix equals the Domestic one in shares of different energy sources. In physical volume it is the amount of available Attributes in the Domestic Residual Mix subtracted with the surplus transferred to the EAM. Because the shares of different energy sources in the surplus are equal to their shares in the Domestic Residual Mix, the shares of energy sources remain unchanged when moving from Domestic to Final Residual Mix in surplus countries.

Equation 11: Volume of Energy Source x in the Final Residual Mix of Surplus Country y

$$Domestic\ Residual\ Mix_{Energy\ Source_x, Country_y} - Contribution\ to\ the\ EAM_{Energy\ Source_x, Country_y} = Final\ Residual\ Mix_{Energy\ Source_x, Country_y}$$

Equation 12: Volume of Final Residual Mix of Country y

$$Final\ Residual\ Mix_{Country_Y} = \sum_{x=1}^{n} Final\ Residual\ Mix_{Energy\ Source_x, Country_y}$$

where n is the number of the Energy Sources

The above equations are useful to calculate the exact Energy Source volumes but conceptually for country with Attribute surplus the Final Residual Mix (shares) are the same as Domestic Residual Mix shares, and the Final Residual Mix volume is the same as Untracked Consumption volume, which is presented in following Figure 15.

Figure 15: Determining Final Residual Mix for surplus country.

3.3.3 European Attribute Mix

All surpluses are collected into a virtual pool of Attributes, the European Attribute Mix. The volume of each energy source in the EAM is the total of all contributions from all Surplus countries (Equation 10). The volume of the whole EAM is hence the total contribution of all energy sources (Equation 13, Figure 13) from all countries and the share of an energy source in the EAM (Equation 15) is the content of that energy source in the EAM divided with the total volume of the EAM (Equation 14). All these steps together all visualised in the Figure 16.

Equation 13: Volume of Energy Source x in the EAM

$$EAM_{Energy\ Source_x} = \sum_{y=1}^{n} Contribution\ to\ the\ EAM_{Energy\ Source_x, Country_y}$$

where n is the number of countries

Equation 14: Volume of the EAM

$$EAM = \sum_{x=1}^{n} EAM_{Energy\ Source_x}$$

where n is the number of the energy sources

Equation 15: Share of an Energy Source x in the EAM

$$\%\ in\ the\ EAM_{Energy\ Source_x} = \frac{EAM_{Energy\ Source_x}}{EAM}$$

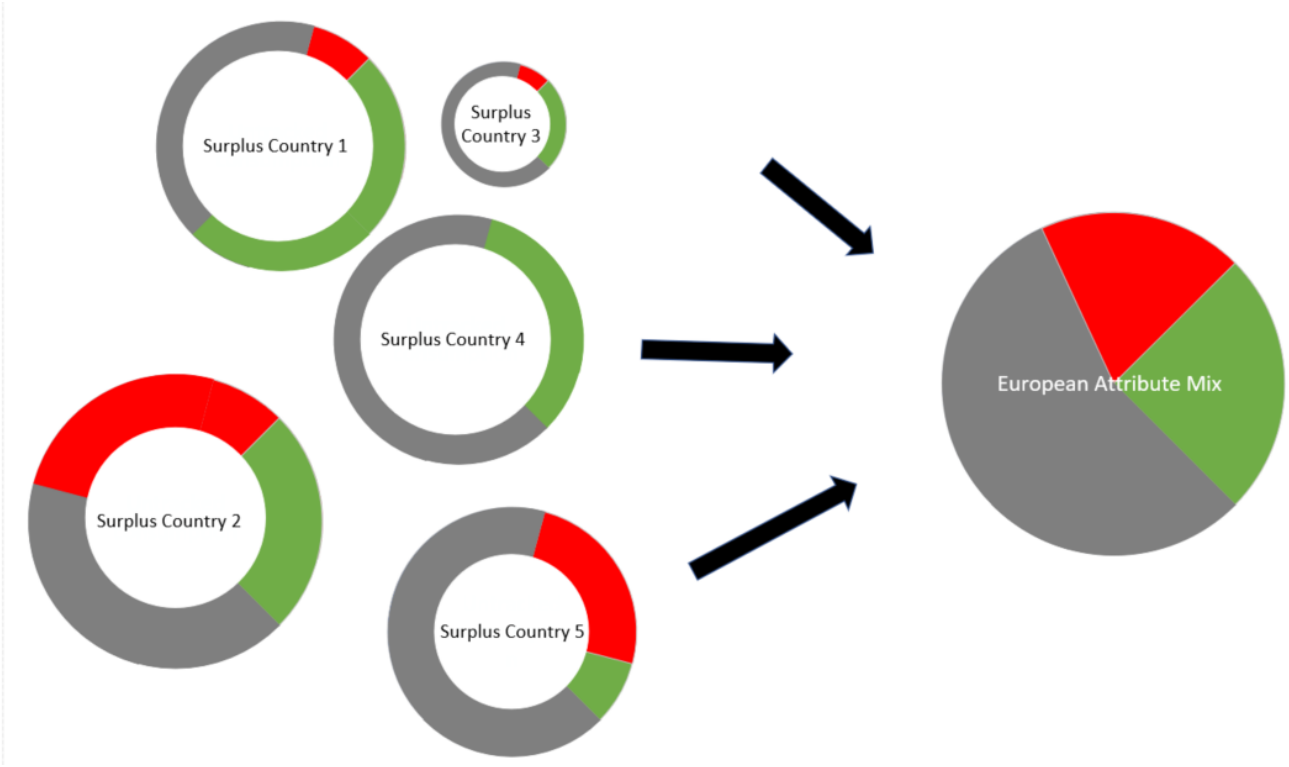


Figure 16: European Attribute Mix is a collection of national Attribute surpluses

3.3.4 Final Residual Mix in Deficit Countries

Once the EAM is established, it can be used to fill in the deficits in the deficit countries. Deficit countries take in the volume of deficit (Figure 17) from the EAM according to the shares of different energy sources in the EAM (Equation 16, Figure 18). These are added to the Domestic Residual Mix to constitute the Final Residual Mix of the deficit country (Equation 17, Equation 18, Equation 19 and Figure 19).

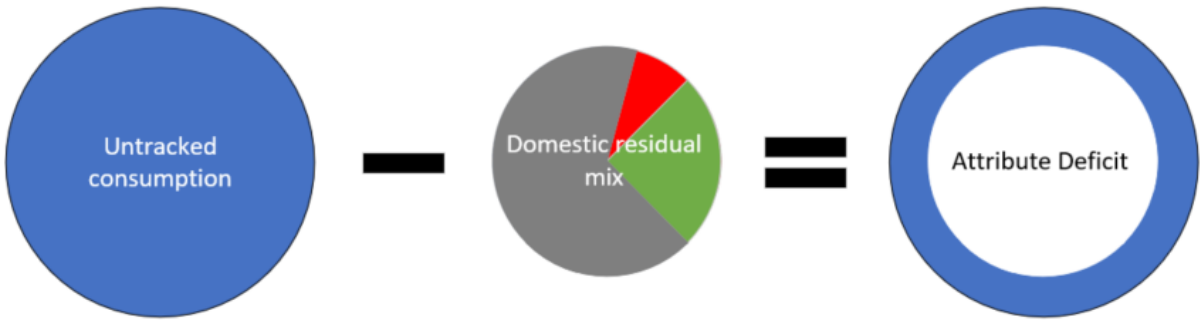


Figure 17: Determining Attribute deficit.

Equation 16: Intake of Deficit Country y for Energy Source x from the EAM

$$Deficit_{Country_y} * \%in\ the\ EAM_{Energy\ Source_x} = Intake\ from\ the\ EAM_{Energy\ Source_x Country_y}$$

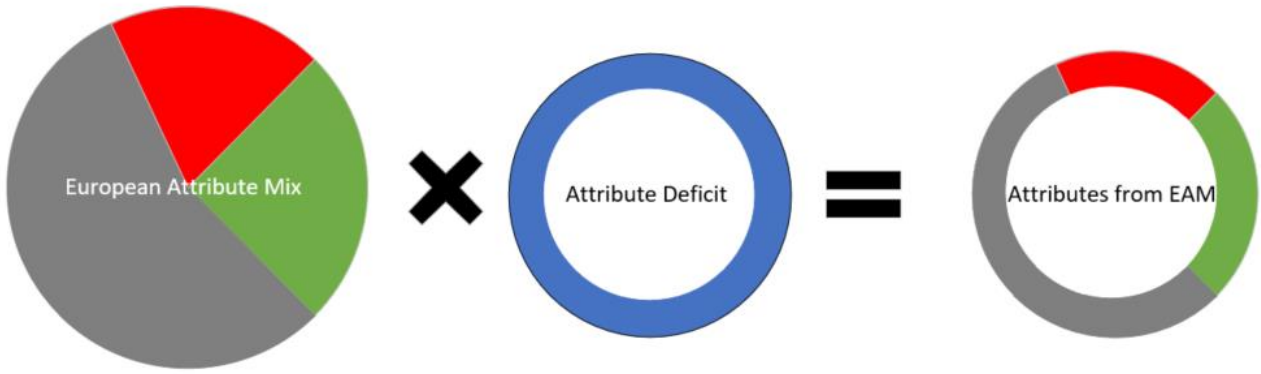


Figure 18: Fullfilling deficits from EAM

Equation 17: Content of Energy Source x in the Final Residual Mix of Deficit Country y

$$Domestic\ Residual\ Mix_{Energy\ Source_x Country_y} + Intake\ from\ the\ EAM_{Energy\ Source_x Country_y} = Final\ Residual\ Mix_{Energy\ Source_x Country_y}$$

Equation 18: Volume of Final Residual Mix of a country y

$$Final\ Residual\ Mix_{Country_Y} = \sum_{x=1}^{n} Final\ Residual\ Mix_{Energy\ Source_x, Country_y}$$

where n is the number of the Energy Sources

Equation 19: Share of Energy Source x in the Final Residual Mix of Deficit Country y

$$\%\ in\ the\ Final\ RM_{Energy\ Source_x Country_y} = \frac{Final\ Residual\ Mix_{Energy\ Source_x Country_y}}{Final\ Residual\ Mix_{Energy\ Source_x}}$$

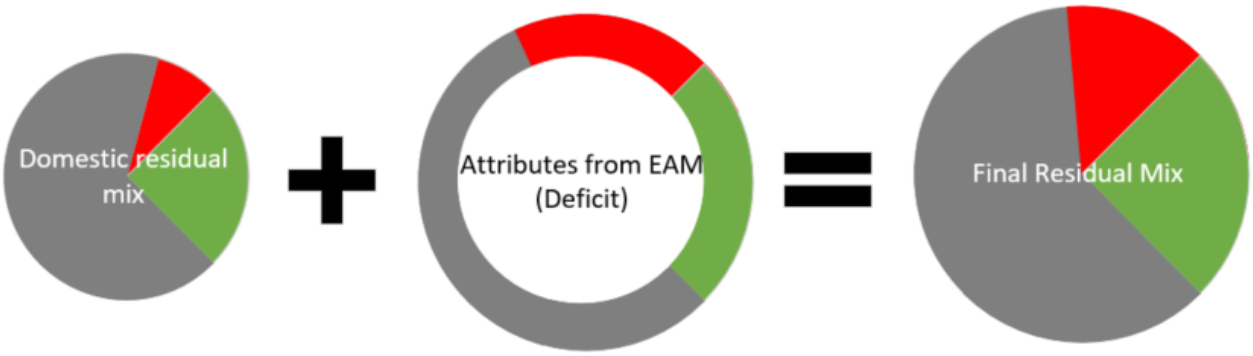


Figure 19: Determining Final Residual Mix for deficit countries

3.3.5 Environmental Indicators

For surplus countries, after deriving the CO_2 of the Domestic Residual Mix (see chapter 3.2.4) the surplus CO2 is fed into the EAM by multiplying the CO_2 factor of the Domestic Residual Mix with the surplus. This doesn't need to be done for each energy source separately because the surplus mix is identical to the Domestic Residual Mix.

CO_2 factor of the EAM is derived by dividing the fed in CO2 with the total surplus (Equation 21). This factor constitutes the CO_2 factor which is used to fill up deficits in deficit countries by multiplying it with the deficit of each respective country Equation 22.

The quantity of CO_2 in Final RM for each country is the quantity of CO_2 in Domestic RM deducted/added with CO_2 fed to / taken from EAM.

Equation 20: Volume of CO_2 in EAM

$$\sum_{y=1}^{n}(CO_2\ factor\ in\ Domestic\ RM_{Country_y} * Contribution\ to\ the\ EAM_{Country_y}) = CO_2\ in\ EAM$$

where n is the number of countries.

Equation 21: CO_2 factor of EAM

$$CO_2\ factor\ of\ EAM = \frac{CO_2\ in\ EAM}{EAM}$$

Equation 22: CO_2 emissions of a deficit country

$$CO_2\ factor\ in\ RM_{Country_y} = \frac{CO_2\ factor\ of\ EAM * Deficit_{Country_y} + CO_2\ in\ Domestic\ RM_{Country_y}}{Final\ Residual\ Mix_{Country_y}}$$

For surplus countries, CO_2 factor in Final RM is equal to the CO_2 factor in Domestic RM, because moving surplus to EAM affects only to the size of the RM and not the energy source mix in it.

Equation 23: CO_2 emissions of Final Residual Mix

$$CO_2\ in\ Final\ RM_{Country_y} = CO_2\ factor\ in\ RM_{Country_y} * Final\ Residual\ Mix_{Country_y}$$

Same calculation is used for determining the Highly active radioactive waste by replacing the CO_2 factor with the Radioactive waste factor.

3.4 Total Supplier Mix

Total supplier mix (TSM) means the total volume of Attributes disclosed in a country, both explicitly tracked and those disclosed using the Residual Mix. It is obtained by summing the volume of Cancellations per Attribute with the Final Residual Mix (Equation 24). In physical size it equals the total electricity consumption in the country (because Untracked Consumption = consumption – Cancellations).

Equation 24: Volume of Energy Source x in Total Supplier Mix

$$TSM_{EnergySource_xCountry_y} = Final\ RM_{EnergySource_xCountry_y} + Cancelled\ Attributes_{EnergySource_xCountry_y}$$

The energy source shares of TSM are calculated by dividing the individual energy source volumes with the total consumption of the country:

Equation 25: Share of Energy Source x in the total supplier mix of Country y

$$\%\ in\ the\ TSM_{EnergySource_xCountry_y} = \frac{TSM_{EnergySource_xCountry_y}}{Consumption_{Country_y}}$$

Figure 20 collects the previous equations to one figure of determining total supplier mix.

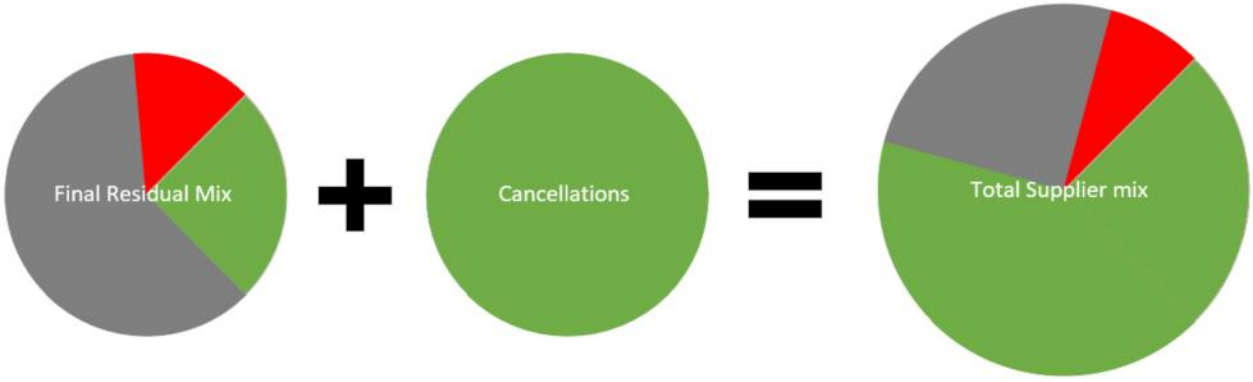


Figure 20: Determining total supplier mix

Environmental indicators of the total supplier mix are calculated by summing the volume of the indicator of Residual Mix to that of tracked consumption. The sum is then divided by the volume of electricity consumption in the country to obtain the value per kWh of average consumption.

Equation 26: CO2 emissions of Total Supplier Mix

$$CO_2\ in\ Total\ Supplier\ Mix = CO_2\ in\ Final\ RM + \sum_{x=1}^{n}(Cancelled\ attributes_{Energy\ Source_x} * CO_2Factor_{EnergySource_x})$$

where n is the number of energy sources.

Equation 27: CO2 emissions factor of Total Supplier Mix

$$CO_2\ factor\ of\ Total\ Supplier\ Mix = \frac{CO_2\ in\ Total\ Supplier\ Mix}{Consumption_{Country_y}}$$

3.5 Process description

The Residual Mix Calculation process shall be initiated annually by sending data collection requests to competent bodies after the recommended disclosure deadline 31.3. The first version of the Residual Mix will then be calculated using the best data available on April 21. The results of the first calculation shall be sent to the AIB for circulation among members by May 5 and published shortly after.

The second and final version of the Residual Mix shall be published by June 20 using data available June 6. Competent Bodies not answering to the data collection request are reminded twice: once before each data deadline. Data from both Competent Bodies and central sources is checked for plausibility by comparing it to other data. Suspected errors in data are checked in cooperation with the data source when time permits.

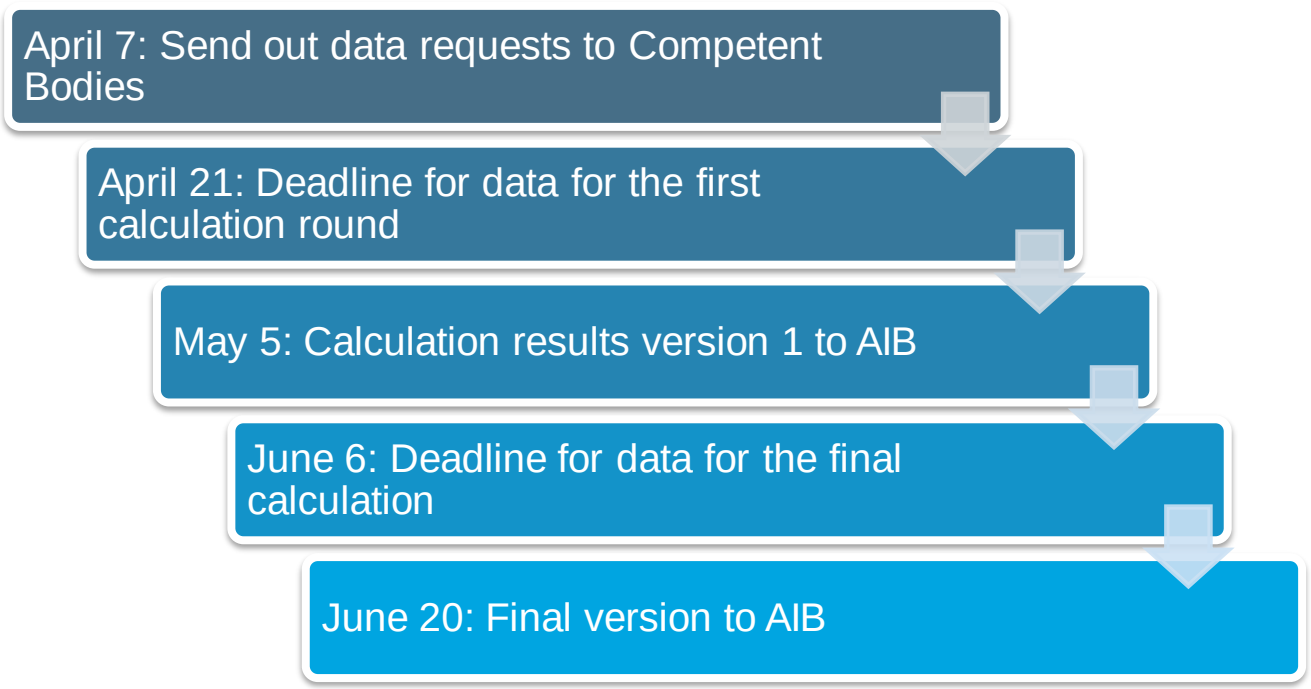


Figure 21. Calculation timeline

4. References

BDEW (2014). Leitfaden “Stromkennzeichnung”, Berlin, Oktober 2014

Bauer, C. 2008. Life Cycle Assessment of Fossil and Biomass Power Generation Chains An analysis carried out for ALSTOM Power Services. Paul Sherrer Institut (PSI). PSI Bericht Nr. 08-05, ISSN 1019-0643 http://ventderaison.eu/documents/PSI-Bericht_2008-05.pdf .

Bauer, C. 2014 Email confirmtion of December 4th 2015 from Christian Bauer (Paul Scherrer Institut (PSI) and Ecoinvent) to Hanne Lerche Raadal about the use of the Ecoinvent database for Residual Mix calculations.

DECC (2014), Fuel Mix Disclosure Data Table, 2014

Dong Energy A/S, Energi.dk, Vattenfall 2010: Livscyklusvurdering Dansk el og kraftvarme (Life Cycle Assessment of Danish electricity and heat), http://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Klimaogmiljo/LCA%20-%20Dansk%20el%20og%20kraftvarme%202008.pdf

Ecoinvent v. 3.1 Database. The EcoInvent database for processes, products and transport. Integrated in the life cycle software tool SimaPro (Pré)., Available at: http://www.ecoinvent.org/

Fritsche, U and Rausch, L (2009). Life Cycle Analysis of GHG and Air Pollutant Emissions from Renewable and Conventional Electricity, Heating, and Transport Fuel Options in the EU until 2030. ETC/ACC Technical Paper 2009/18 June 2009. http://acm.eionet.europa.eu/reports/docs/ETCACC_TP_2009_18_LCA_GHG_AE_2013-2030.pdf

GEMIS (Globales Emissions-Modell integrierter Systeme). Downloaded from http://www.iinas.org/gemis.html (Jan 2015)

IAEA PRIS. The IAEA Power Reactor Information System (PRIS), 2015, https://www.iaea.org/pris/

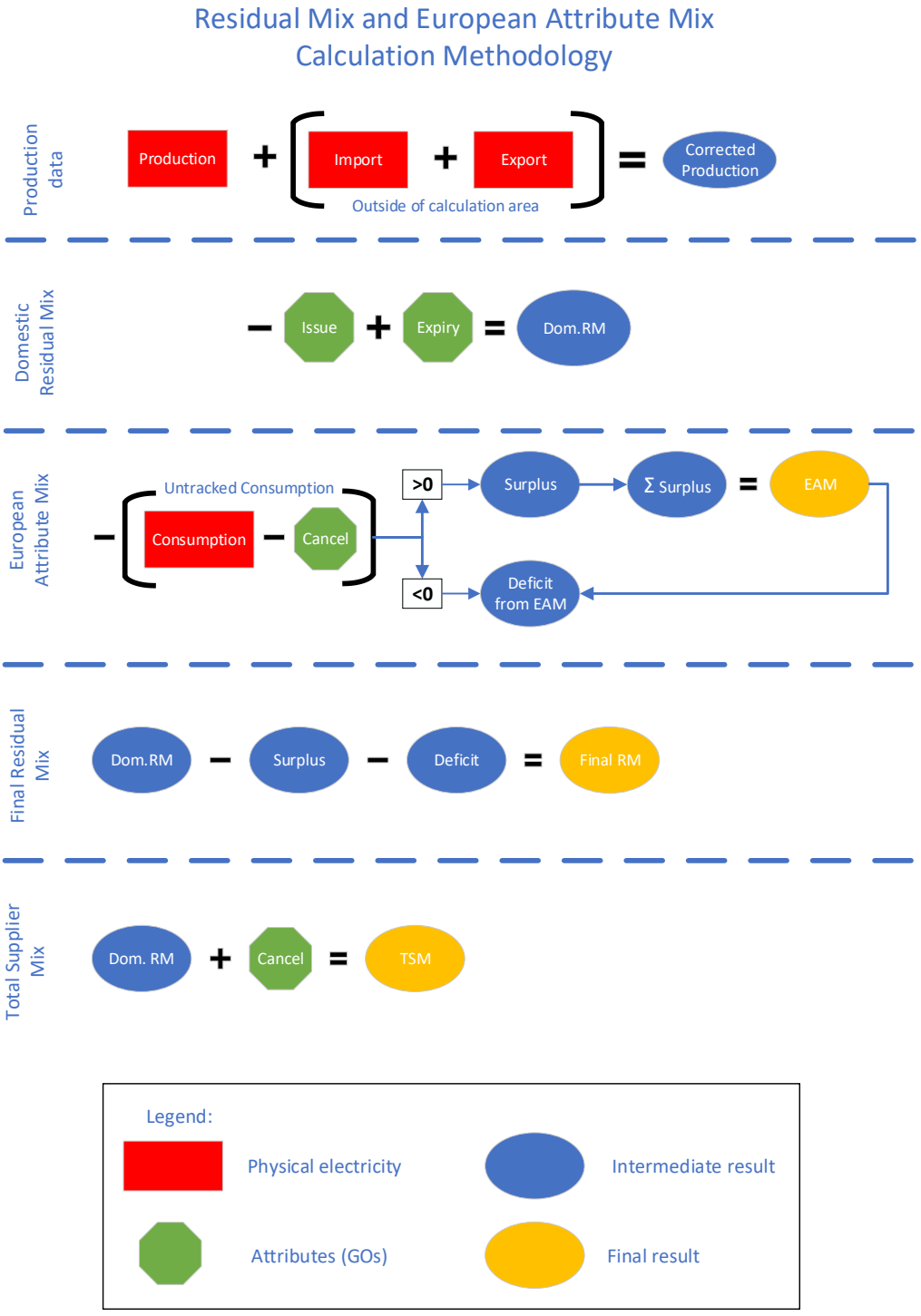
Klimscheffskij M, Lehtovaara M and Aalto M, 2015, The Residual Mix and European Attribute Mix Calculation, Methodology Description of the RE-DISS II Project. Available at http://reliable-disclosure.org/upload/234-D7.2_RMCalculation.pdf

Platts: The Platts World Database, 2014

RE-DISS II, 2015, http://reliable-disclosure.org/upload/222-RE-DISS_Best_Practice_Recommendations_v2.4_Final.pdf

Treyer and Bauer 2013. Life cycle inventories of electricity generation and power supply in version 3 of the ecoinvent database—part I: electricity generation. The International Journal of Life Cycle Assessment, 27 Nov 2013, doi:10.1007/s11367-013-0665-2

Annex A



Note: in this schematic drawing the physical electricity import + export is shown in simplified manner. Realistically intermediate Domestic Residual Mix is required to calculate exports. See chapter 3.2.2 Considering Electricity Imports/Exports with Export Countries.

Annex B

Mapping of ENTSO-E energy source categories to energy source breakdown as shown in 3.1.1 Energy Source breakdown.

ENTSO-E Energy Sources	***RMC Energy Sources***
Nuclear net generation	*NU Nuclear*
Of which Wind offshore	*RE Wind*
Of which Wind onshore	*RE Wind*
Of which Solar PV	*RE Solar*
Of which Solar Thermal	*RE Solar*
Of which Biomass	*RE Biomass*
Of which Biogas	*RE Biomass*
Geothermal net generation	*RE Geothermal*
Renewable Waste net generation	*RE Unspecified*
Of which Hydro Pure storage	*RE Hydro*
Of which Hydro Run-of-river and pondage	*RE Hydro*
Of which Hydro mixed pumped storage (renewable part)	*RE Hydro*
Of which Hydro Marine (tidal/wave)	*RE Hydro*
Other renewable net generation	*RE Unspecified*
Of which Fossil Brown coal/Lignite	*FO Lignite*
Of which Fossil Coal-derived gas	*FO Gas*
Of which Fossil Gas	*FO Gas*
Of which Fossil Hard coal	*FO Hard coal*
Of which Fossil Oil	*FO Oil*
Of which Fossil Oil shale	*FO Oil*
Of which Fossil Peat	*FO Lignite*
Of which Mixed fuels	*FO Unspecified*

Of which Other fossil fuels	*FO Unspecified*
Non-renewable Waste net generation	*FO Unspecified*
Other non-renewable net generation	*FO Unspecified*
Non-identified net generation	*Pro-rata to other energy sources*