Transition Towards Carbon Free Electricity - Developing CO_2 Emission Assessment Software For Corporate Use

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Abstract

The development of renewable energy technologies has enabled the increment of the industrial scale renewable energy generation around the world. Currently in most of the countries electricity users are able to choose the origin of the electricity provided to their houses. However, since after the electricity enters the grid it cannot be tracked down, there emerged the need for tools enabling the transparency of the electricity sourcing and its traceability, especially for non-domestic users who are obliged to account for their greenhouse gases emissions. The purpose of this thesis was to create a tool that will allow the corporates to assess their electricity-related CO_2 emissions in an easy and fast way, with the use of three different approaches. The software also addresses an important issue connected with the current emissions reporting system and introduces the practical implementation of the hourly-matching emissions estimation procedure. The hourly-matching procedure may soon become more present on the energy market, as the interest in the topic raises every year and more companies decide to commit to 100 percent renewable energy and search for ways to reliably prove it. The evaluation of the tool that included generating results for different users located in different locations shows that in the majority of the cases there exists a significant difference (up to 25%) in the CO_2 emissions calculated using real-time (hourly) emission accounting in comparison to the averaged (yearly) emission accounting, which indicated the need of reforming the emissions accounting market.
Keywords: CO_2 emissions, GHG accounting, electricity, transparency, hourly accounting

1. Introduction

There was a point in the recent history of humanity, when the environment became progressively damaged by the consumerism of the human race and the increase of demographic growth, and it started to send us warnings about the consequences of our destructive activity. The current state of matter is already described as a climate crisis. Warming seas, the retreat of glaciers, shrinking ice sheets, sea-level rise, animal species extinction, droughts, bushfires and other extreme events are only a few examples of the changes happening around the world. Earth's average temperature has risen 1.1 Celsius degree since 1880 [1], and while it can appear not to be a significant increase, it is actually quite an unusual event in the history of humanity. Moreover, small temperature changes are related to enormous changes in the ecosystem. Climate change and related environmental degradation are an existential threat to the whole world. Scientists around the world are unanimously agreeing, that soon we will have to face a so-called tipping point, when climate changes reach such a scale and level, that it will not be possible to reverse them. However, since we haven't reached this point yet, we can still act and prevent the irreversibility of climate change.

One of the most solid arguments proving the human impact on climate change is the historical level of CO_2, measurements of which are available up to 800 000 years ago. In Figure 1 it can be observed that before modern times, the ecosystem could perfectly balance itself. At the moment, where human activities started to have a significant impact on the environment, the balance has been disrupted. The pace of changes happening since the beginning of industrialization can be defined as exponential [1]. This change is visible in the form of CO_2 level anomaly in Figure 1 in the point of most recent history, where the CO_2 level surges over 400 CO_2 ppm, almost doubling its mean historical value. Currently, the CO_2 level reached the value of 418 ppm [1], which is the record highest value in history.

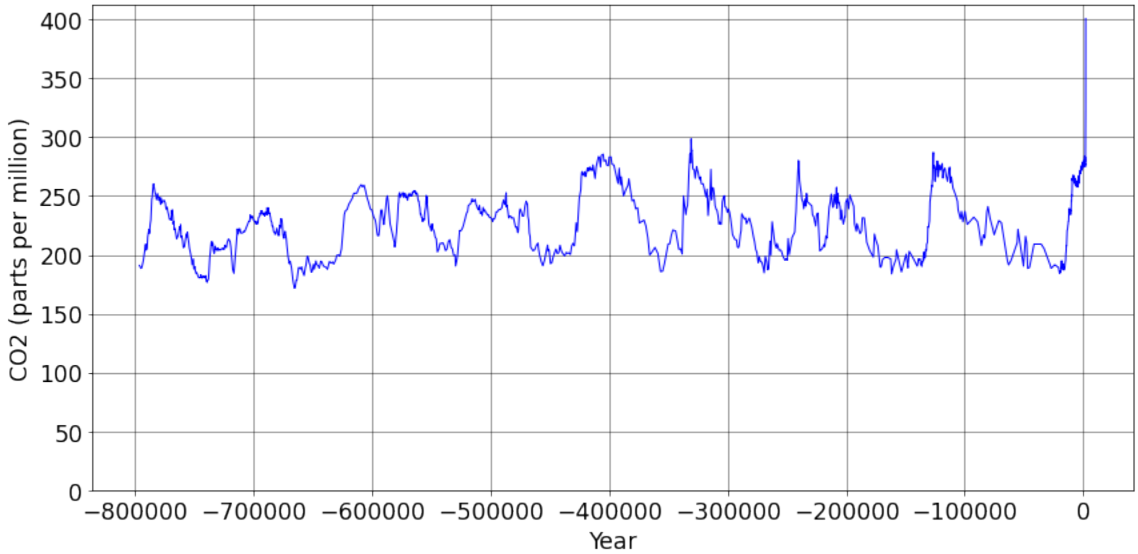

Figure 1: Carbon dioxide level from 800 000 years before year 0 until today [1]

The largest driver of global warming is the emission of greenhouse gases, of which over 90% is carbon dioxide (CO_2) and methane (CH_4). The majority of anthropogenic CO_2 is caused by the combustion of fossil fuels, such as coal, petroleum and natural gas. In Europe, the electricity generation sector is responsible for around 30% of the EU's greenhouse gases emission [2], and since it has been proven to be the main reason for the emission of greenhouse gases, a range of legislations have been released in order to regulate the scale of the emissions.

In order to meet the goals dictated by the directives, a certain level of control over the industry and domestic users is needed. The attention focuses especially on the industrial and commercial users since the residential sector accounts only for 26% of the total final electricity consumption [3] and is far more difficult to control.

The Corporate Standart is the most most widely used document containing the guidelines for GHG emission accounting in the world, recognized by many authorities. It categorizes the emissions into three scopes, based on their origin (direct emissions from company's activities, indirect emissions connected with purchase of electricity, steam, heating and cooling, all other indirect emissions from company's activities) [4].

This division, however, was not fully effective since it would not take into account the choices of contracts that companies are making. Scope 2 Guidance, an amendment to the Corporate Standard, has been released in January 2015. It was the first major revision to the Corporate Standard [4]. The main change that it introduced, was the creation of two ways of Scope 2 emissions reporting - the allocation methods, that assign emissions to end-users. Companies were strongly encouraged to publish numbers resulting from calculations based on both new methods.

The first method is called the location-based method, and it reflects the average emission intensity of grids that provide electricity (mostly using grid-average emission factor data) in the location where the consumption occurs. The second method, called the market-based method takes into account the electricity contract that the user has signed. It reflects emissions that companies have purposefully chosen. In this method, emissions are estimated based on any type of contract between two parties for the sale and purchase of electricity unbundled or bundled with certificates of energy generation.

However, there exists an important problem with the way that the CO_2 accounting system works, which has not been addressed yet. In both cases of location-based and market-based methods, values used in calculations are yearly averages. This means that insight on what exactly happens during the whole year of electricity consumption is not included.

The concept of real-time emissions tracking or hourly emissions accounting has emerged as a response to this problem. The hourly emission accounting is about matching the user's consumption with renewable electricity generation with an accuracy of 1 hour. This means that for every hour in a year, the renewable energy source, electricity from which the user has contracted, produces enough energy to cover the user's electricity consumption. General rules for the hourly emission accounting are the same as in yearly accounting - when we need to match e.g. 10 MWh of yearly consumption with contracts that state the purchase of 10 MWh of renewable energy in this year - but now the period is refined to hours. Therefore, for every hour, during which we consumed e.g. 5 kWh, we need to provide a certificate from the source, that produced the green electricity at this specific hour.

For the companies that want to reduce their emissions originating from electricity consumption (Scope 2 emissions), there are several options currently available on the market, each of them having different features and environmental impact. Most common ways of offsetting the Scope2 CO_2 emissions are renewable energy contractual instruments. They are any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims [4]. Contractual instruments have different features that influence the decision of which contract to choose. The main features are quantitative features such as unit price, contract's length, contract's capacity, but also qualitative features such as additionality, transparency and complexity of the project. The electricity generation source can be chosen by the consumer in the case of each contractual energy instruments.

2. Software design

For the purpose of this thesis, dedicated software has been created. The software allows the user to calculate their CO_2 emissions using 3 different methods:

1. Yearly averaged CO_2 emissions with the use of grid carbon intensity provided by external databases (European Environmental Agency, International Energy Agency),
2. Yearly averaged CO_2 emissions with the use of grid carbon intensity calculated based on the location's electricity generation mix,
3. Sum of hourly CO_2 emission in $kgCO_2$ estimated with the use of the hourly matching procedure for one year.

Figure 2 presents the results generated for a sample user's data. Together with the CO_2 results, the user's electricity consumption plot is generated. The plot is a representation of the major trends in the industry chosen by the user and is scaled to the rest of the user's input and the total electricity consumption. The electricity consumption plot is vital for the hourly-matching procedure for emissions assessment. It is displayed together with the results in order for the user to check if, according to his best knowledge, the electricity consumption plot represents reality well.

Additionally, the user has the possibility to see how his emissions will change if he acquires a renewable energy contractual instrument. The user can choose among 7 types of renewable energy contractual instruments:

- European Guarantees of Origin
- National Guarantees of Origin
- Off-site Solar Power Purchase Agreement
- Off-site Wind Power Purchase Agreement
- On-site Solar Power Purchase Agreement
- On-site Wind Power Purchase Agreement
- Green Tariffs

All of the contractual instruments will result in reducing the market-based emissions to 0. Each of the instruments has different features. The software will display a window containing the specifications of the instruments, which are:

1. Contractual instrument's description,
2. The number of units that the user has to purchase to offset his market-based emissions,
3. The user's market-based emission,
4. The user's location-based emission after acquiring the contractual instrument,
5. The amount of the avoided CO_2 emission,
6. The unit price of the contractual instrument and the total cost that the user will have to cover to purchase the contractual instruments that will completely offset his market-based emissions,
7. The source of the price,
8. Advantages and disadvantages of the contractual instrument,
9. The chart showing at what hours the renewable energy produced from the chosen contractual instrument's energy source covers the user's electricity consumption and when it doesn't,
10. The summary of the contractual instrument, containing the assessed real impact, the recommended company's size and the contractual instrument's capacity,
11. The comparison of contractual instruments in a form of a table.

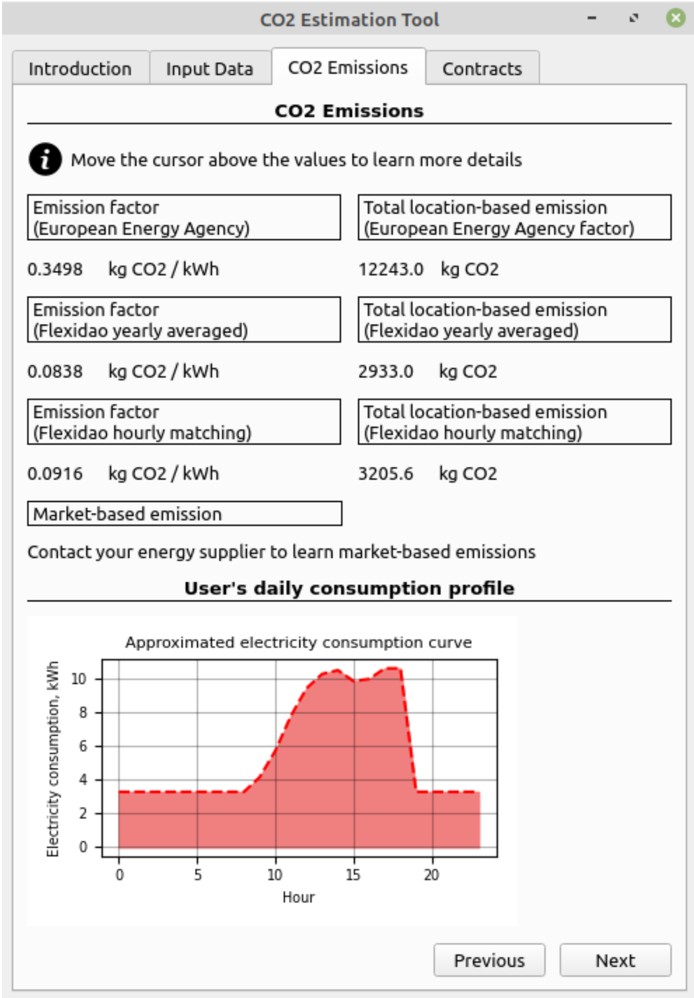

Figure 2: GUI CO_2 Emissions Tab

In Figure 3 the details of one chosen contractual instrument with the example data are shown.

The software has been designed in such a way that it eliminates the need for providing specific hourly electricity consumption data and at the same time requires minimum input from the user. The software uses hourly time series data in its calculations, but since accessing the user's hourly consumption data is impossible if he does not have smart meters installed, which would severely limit the group of users that can use the tool, the approximated time series are created by the software based on a short survey.

The user is providing the following data (types in or chooses from the drop lists):

- Country
- Electricity consumption
- Type of industry
- The number of operating days in a week
- The start hour of the active operation during the single-day period
- The end hour of the active operation during the single-day period
- Year

3. Methodology

3.1. The Database

The database is the main component needed for the program to work. Setting up the database is an automatic process, and can take up to an hour, depending on the internet speed and computational power. Creating the database consists of 4 steps:

1. Downloading the electricity generation mix data via API request call from ENTSOE (European Network of Transmission System Operators for Electricity) [5]. Because the data acquired from the ENTSOE database is raw, data cleaning needs to be applied. Linear interpolation is used to fill the entries with missing data. Because the data have different sampling frequency, all of them are resampled to full hours. Data is written in a separate file for each country. The format of the name of the downloaded data is 'year'+'country code'.

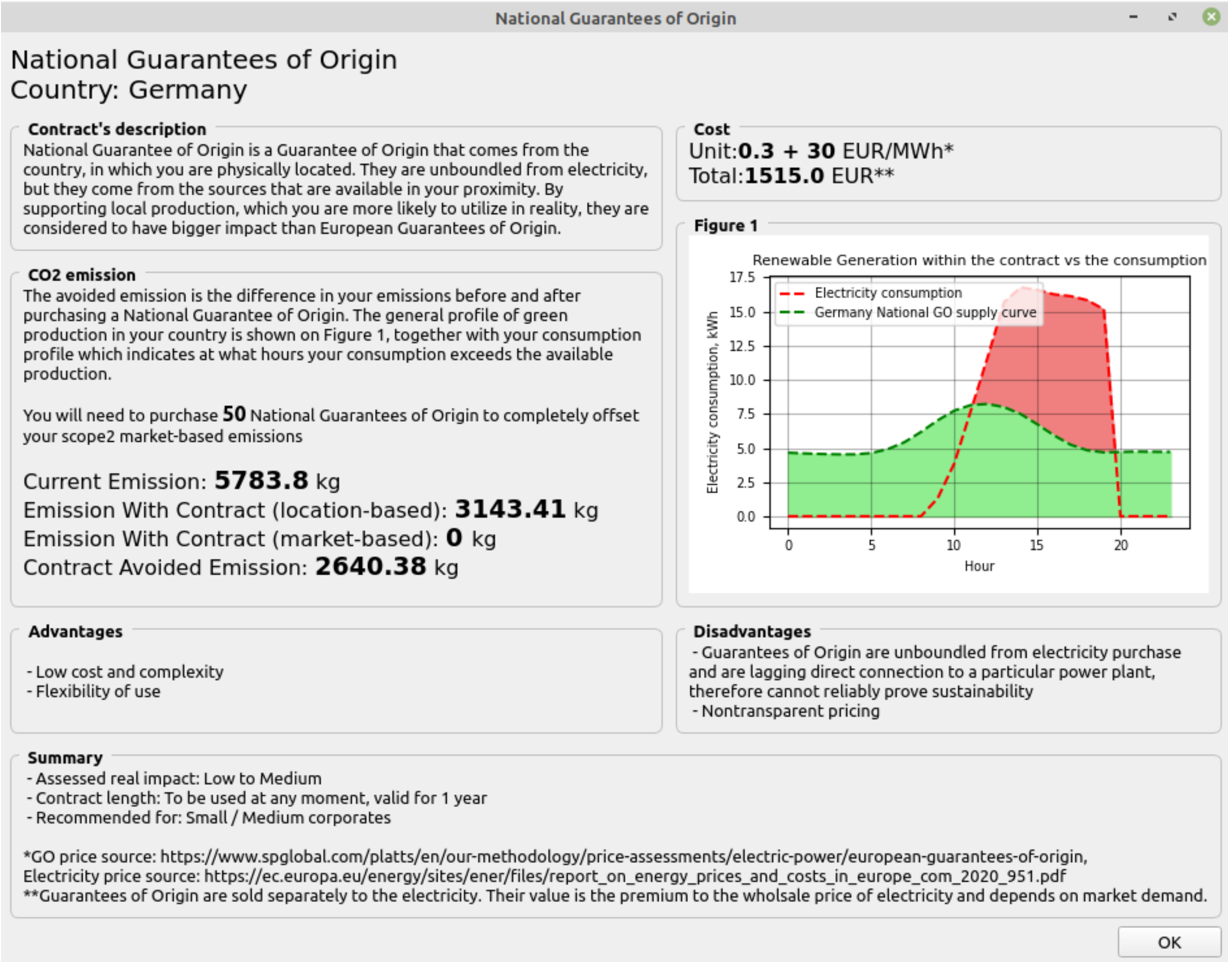

Figure 3: GUI Contracts Details - National GO

The extension of the files is .csv. Country codes are commonly used abbreviations (e.g. DE for Germany). Additionally, the data containing electricity imports and exports between the countries is downloaded.

2. Calculating grid carbon intensity for every hour for all the files. In this step, we want to calculate the CO_2 emission in kg/kWh based on the mix of the sources generating the electricity. In order to do that, we need to know how much kg of CO_2 is emitted by generating 1 kWh of electricity from a given source. Only direct emissions are considered when performing the calculations. The CO_2 emission factors come from an external source [6]. The CO_2 emission factor of total electricity production in each hour in a given country is a weighted average of the CO_2 emission factors of the individual electricity sources.

3. Because of the constant exchange of electricity between the countries, the grid carbon intensity depends not only on the CO_2 emission factor of generated electricity but also on the emission factor of imported electricity. Therefore, it is needed to account for the electricity imports between the countries. In order to include the CO_2 emission factor of electricity flow into and out of the country, a set of energy balance equations needs to be written, where each equation represents a single country. For the country 'i' [7]:

$$C_i = \Sigma_m P_{i,m} + \Sigma_j I_{i,j} \tag{1}$$

Where C_i is the electricity consumption in kWh for the country 'i', $\Sigma_m P_{i,m}$ is the sum of electricity production in kWh originating from the source 'm' in the country 'i' and $\Sigma_j I_{i,j}$ is the sum of electricity imported from country 'j' to country 'i' in kWh.

We assume that the transmission cost is negligible. In a country, that exports more electricity than it imports, the import component will have a negative sign. In Equation 1, the final amount of energy physically consumed in a given country should be equal to the whole energy generated within the country from the number of sources 'm' plus the energy that was imported to the country from the number of other countries 'j'. Adding to Equation 1 the CO_2 emission intensity ($kgCO_2$/kWh) component (χ), we obtain the following:

$$\chi_i \cdot C_i = \Sigma_m \chi_m \cdot P_{i,m} + \Sigma_j \chi_j \cdot I_{i,j} \quad (2)$$

In Equation 2, the emission intensity of the consumption in the given country is equal to the emission intensity of the generation + emission intensity of the imported energy (associated with different intensities depending on the country of origin). Balance equations for all available locations will create a set of linear equations, that can be represented in a form of a matrix (Equation 3).

$$\begin{bmatrix} P_1 + I_1 & -I_{1,2} & \cdots & -I_{1,n} \\ -I_{2,1} & P_2 + I_2 & \cdots & -I_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ -I_{n,1} & -I_{n,2} & \cdots & P_n + I_n \end{bmatrix} \begin{bmatrix} \chi_1 \\ \chi_2 \\ \vdots \\ \chi_n \end{bmatrix} = \begin{bmatrix} \sum_m(\varepsilon_{1,m}) \cdot P_1 \\ \sum_m(\varepsilon_{2,m}) \cdot P_2 \\ \vdots \\ \sum_m(\varepsilon_{n,m}) \cdot P_n \end{bmatrix} \quad (3)$$

4. Inside the matrix, each country's value has an index containing their country code (1 to n). In the case of electricity import component 'I', there are 2 numbers in the index, denoting the direction of the electricity flow - the first number is the country which exports electricity and the second number is the country that imports electricity. χ_1 to χ_n are unknown CO_2 intensity values. The CO_2 emission intensity of different energy sources within a country are denoted with $\varepsilon_{i,m}$ to $\varepsilon_{n,m}$ and are known values. The electricity sources are denoted with the index 'm'. The sum of the generation of the electricity from 'm' sources of a related emission intensity 'ε' is equal to the total country's electricity generation. Solving this linear system gives us the grid carbon intensity 'χ' for each of the locations. The values being the result of solving the import matrix are called 'consumption emissions' since they are the CO_2 emission intensity of the electricity that is consumed (not only generated) in the given location.

3.2. Calculations

In order to proceed with the hourly matching procedure, we need to know exactly how much electricity the corporate is consuming. Because many companies do not have access to smart meters or more detailed reporting, an approximation needs to be introduced. Based on general trends present in the existing non-domestic market, 6 different categories of industrial electricity consumers have been distinguished [8]. The user chooses the industry group that his company belongs to. Then, based on the hours, that the company is operating within in the day, the electricity consumption curve is adjusted to fit the company's operation habits – the profile is moved and stretched to fit the user's input hours. Next, the electricity consumption curve is scaled to match the amount of electricity consumed in a year. User's total yearly consumption is evenly distributed between all the operating days in a year. The assumption, that the user consumes exactly the same amount during all the operating days is leading to minor errors in the total emission value, which is however the best approximation possible without having the exact hourly data from the user's company.

3.3. Calculating location-based CO_2 emissions

CO_2 emissions are calculated in 3 different ways:

1. Using grid carbon intensity from external sources:
   Using the formula:

   $$m = C_{el} \cdot E \quad (4)$$

   Where m stands for total CO_2 emission in kg, C_{el} defines electricity consumption in kWh and E is the CO_2 intensity in kg/kWh.

   We can calculate the total CO_2 emission in kg based on the user's electricity consumption and the country's grid CO_2 intensity. The CO_2 intensity is externally sourced [6].

2. Using yearly averaged grid carbon intensity calculated from the program's database:
   Using the program's database, we calculate the average CO_2 grid carbon intensity as a simple average of grid carbon intensities every hour for the corresponding country. The equation has a similar form to the equation 4 with the difference in the CO_2 emission intensity component.

   $$m = C_{el} \cdot \sum_h \chi_h / 8760 \quad (5)$$

   Where C_{el} stands for electricity consumption in kWh, χ stands for grid carbon intensity in kg/kWh and h defines an hour.

   The methodology of estimating the χ component is described in this thesis in the beginning of this chapter, with the use of Equations 1, 2 and 3. The grid carbon intensity component is calculated separately for each hour, therefore in order to use it in yearly estimation we use a simple yearly average of all hourly values.

3. Using hourly – matching procedure and values from the program's database:
In order to calculate the total CO_2 emission, we introduce generated by the program electricity consumption profile to the database containing grid carbon intensity. The consumption profile is a list of 24 points. Each value in the list corresponds to the amount of electricity in kWh that a user is consuming during a specific hour. Based on the number of operating days that we take from the user's input data, we assign the list containing points from the operating day to the number of the operating days and we assign the list containing zeros (no consumption, flat profile) to the non-operating days. Now that the amount of electricity consumption in kWh is specified for each hour of the year, we can calculate the total CO_2 emission in kg using the Equation 6. The hourly-matching assessed grid carbon intensity is then calculated by dividing the total CO_2 emission in kg by the user's electricity consumption. It is just an informative value shown in order to notify the user how much CO_2 emission on average 1 kWh of his electricity consumption is causing.

$$m = \sum_{h} C_{el,h} \cdot \chi_h \tag{6}$$

Where $C_{el,h}$ stands for the electricity consumption in one hour period in kWh and χ_h is the grid cabron intensity in one hour period in kg/kWh. The final value m sums up 8760 hourly values for a year period.

3.4. Contractual instruments' details

1. Contractual instruments green electricity generation
The general rule for matching the available renewable electricity production with the user's electricity consumption is as follows: Depending on the contract, different renewable electricity sources are taken into the consideration. The program takes the average of each hour's electricity production and creates a list, which is then normalized. Next, based on the user's electricity consumption the program calculates how many contracts (in case of Guarantees of Origin) or what amount of electricity needs to be purchased to offset the total emission (min capacity is 1MWh for GOs). Then, the amount of produced green electricity is distributed to all days in the year accordingly to the electricity production profile. In the end, it is scaled based on the needed amount of contracts. The green electricity production is shown together with the user's consumption so that the user can see at what hours his company's electricity consumption exceeds the available green electricity production.

2. Contractual instruments CO_2 offset
By purchasing green energy contractual instruments equal to the user's electricity consumption amount, a user can declare his market-based emissions as 0, in case of any contract. Using location-based emissions, we are able to calculate the avoided emission based on the hourly-matching procedure. It is done by simply taking time-series data of the user's electricity consumption and the time-series data of the renewable electricity generation available to the user via the contract, and subtracting the available renewable electricity amount from the user's consumption. If the result is the negative value, we will mark it as 0 (since the emission during this hour will be equal to 0, we cannot have negative emissions). If the result will be a positive value (there is electricity consumption that our green generation does not cover), we will multiply it by the grid carbon intensity for this hour, and the result will be the location-based emission that the user caused during this hour. This operation will be done for all the hours in the time series. Finally, we will sum up all the emissions from the single hours – it is the new location-based total emission for the year. By subtracting this value from the user's total hourly matched location-based emission from the CO_2 Emission Tab we will obtain the avoided emission.

3. Contractual instruments' capacity
In the case of most contracts, the capacity that you need to acquire is based only on your consumption. In the case of Guarantees of Origin and off-site PPA, your consumption is rounded up to the full MWh since the lowest capacity you can purchase is 1 MWh. In the case of Green Tariffs, the capacity you need to acquire is equal exactly to your consumption in kWh – the possible capacity limitations may arise from the retailer side but they need to be evaluated separately for each situation between the contract's sides. In the case of on-site PPA, the capacity that the customer needs to install is calculated [9] [10].

3.5. Assumptions

The program operates under a few assumptions, that make the calculation process fast and requires a minimum data input from the user. The main assumptions are:

1. Even distribution of the consumed electricity between the operating days

2. The chosen amount of the operational days starts on Monday. If the user chooses 3 operational

days, the program will assume that those days are Monday, Tuesday and Wednesday

3. The electricity consumption profiles are generated based on the general trends within the chosen industry. In some cases, they may not perfectly match the user's electricity consumption habits.

4. In the situation when some country lacks some specific kind of data (e.g. Solar generation), the European averages will be shown.

5. In the case of missing entries in the specific country's electricity generation data, interpolation is used for filling in the empty spaces. In the cases when interpolation can not be performed, the empty entries are filled with zeros.

6. In on-site PPA we assume that the user is the owner of the installation and therefore the cost of the investment is shown.

4. Results

The most important application of the software is showing the difference between the amount of CO_2 emission calculated with the use of yearly averages and calculated using the hourly values. In order to examine the effect of using hourly data instead of yearly averaged, a study on the differences between the values has been conducted. The study involved calculating CO_2 emission with the use of hourly values for 3 different users:

1. A permanent use industry sector user, consuming electricity in a constant manner,
2. A retail sector user, consuming electricity during the daytime,
3. A entertainment sector user, consuming electricity at night.

The study has been performed separately for each country available in the database. For all three users, it has been assumed that the amount of 30 000 kWh of electricity is consumed annually. The only difference in the input parameters was the type of industry and consumption hours, which has affected how the user's electricity consumption profile looked. First, the reference value of yearly averaged CO_2 emission was estimated. This value does not take into account the user's electricity consumption pattern. Because all the cases had the same input annual electricity consumption, the yearly CO_2 emission values are the same. Then, the values of CO_2 emission based on hourly calculations have been calculated for all three cases separately.

The study results are visualised in Figure 4, in the form of a bar chart. For each country, three bars having different colours correspond to different users. The values on the y-axis are expressed as percentage values, showing the difference between the current and the reference value of 100%. The value of 100% in the case of each country corresponds to the yearly averaged CO_2 emission value, which is the same for all three cases. The CO_2 emission values calculated with the use of hourly values are presented as a percentage of the reference value.

As expected, the first user characterised by the constant electricity consumption is the closest to the reference value of 100%. For this type of users, the deviation from the reference value does not exceed 2%. The mean value of the results for all countries almost perfectly matches the reference value, as it is equal to 100.2%. The standard deviation of the results is equal to 0.5%.

In the case of the second user, characterised by the electricity consumption during the daytime hours, the values tend to be much lower than the reference value, as low as almost 20%. There are big differences between individual countries, however, the general pattern can quickly be spotted: the user consuming electricity during daytime has on average the lowest CO_2 emission values. The mean value of the results for all countries equals 95%, which shows that on average, the electricity consumer in an arbitrary location is expected to be responsible for 5% lower emissions than the ones reported with the use of annual averages. The standard deviation of the results is equal to 5.9%.

In the case of the third user, characterised by the electricity consumption at night, the values seem to be higher than the reference value, as much as 25% higher. The mean value of the results for all countries equals 105%, so it can be concluded, that on average, the user consuming electricity at night in an arbitrary location will be responsible for 5% higher emissions than the ones reported with the use of annual averages. The standard deviation of the results is equal to 7.4%.

There are several countries that exhibit the CO_2 emission levels for the second (daytime) user that are higher than the reference value, and at the same time, the emission levels for the third (night-time) user are lower than the reference value. It can be concluded, that in these countries the electricity generated at night has a lower CO_2 emission intensity than the electricity generated at night. These countries are France, United Kingdom, Hungary, Ireland, Netherlands, Poland, Portugal and Slovakia. There are many factors that can contribute to a country having a higher grid carbon intensity in the daytime hours. The countries that exhibit lower grid carbon intensity at night, as opposit to lower grid carbon intensity during the day, characterize with very high percentage content of conventional fossil fuels and nuclear energy, that

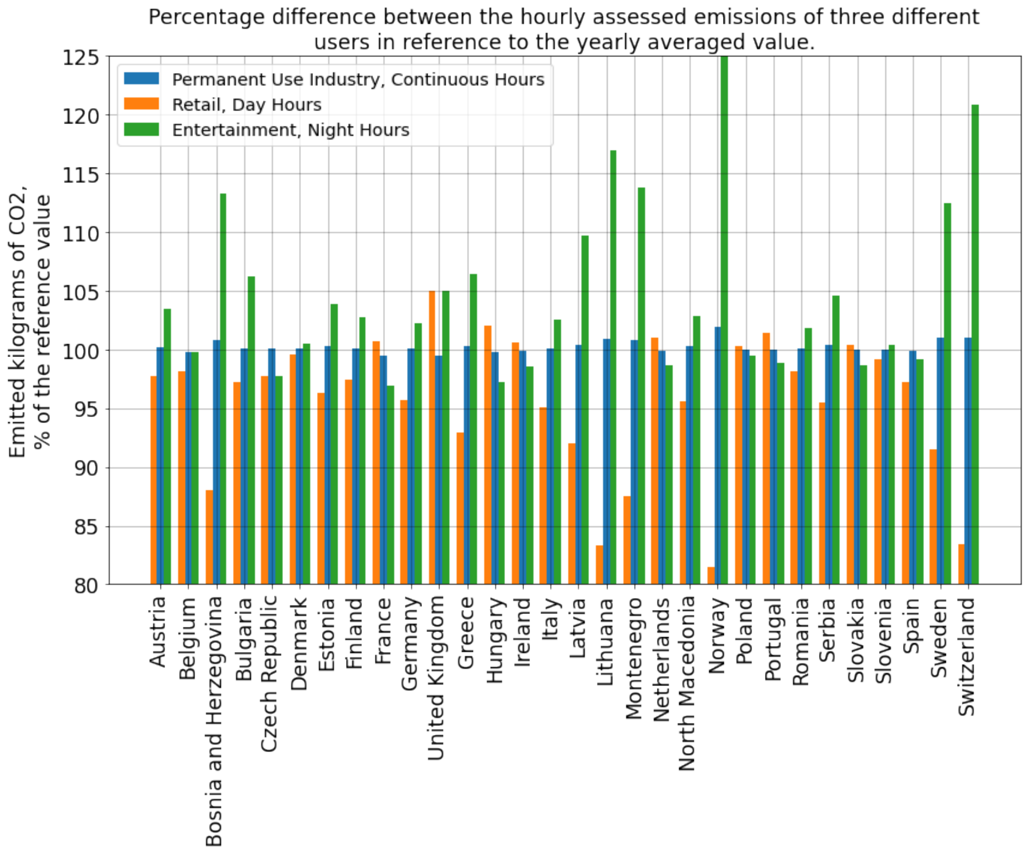

Figure 4: Comparison of the CO_2 emission for different electricity consumption patterns, hourly calculations. Yearly average as a reference point, marked by 100% value.

are known for being independent on any external conditions. Therefore, the grid carbon intensity is expected to be more stable throught the course of the day. The fact, that in those countries the grid carbon intensity can be higher during the daytime, may be caused by the peak demand hours occuring in the morning and late afternoon. During the peak hours, more conventional energy sources may be engaged in the electricity production, in order to meet the required level of electricity production. Another thing is that sometimes measurement errors occur, there are missing series of data or different types of anomalies can happen due to random events, which can possibly impact the final results, especially of a dataset that consists of values of a period of 1 year.

To sum up the study, there definitely exists a difference in the CO_2 values emitted by the users with different electricity consumption patterns, which indicates the need of reforming the emissions reporting sector and introducing hourly emmisions accounting as opposite to the yearly emissions accounting that is currently commonly used. It can be noticed, that the countries with the higher percentage content of renewable energy sources in the grid are experiencing higher fluctuations of the grid carbon intensity values between different hours. As the share of renewable energy sources in the countries' electricity mix is only expected to rise in the next years, the differences between the CO_2 emitted from electricity use at different hours will also increase.

5. Conclusions

This thesis presented software for CO_2 emission estimation dedicated for corporate use, specifically for energy and sustainability managers. The program offers 3 different types of yearly CO_2 emission calculations, and generates estimated details of green electricity contracts based on the user's input data.

There is a significant difference between CO_2 emission results calculated by the program with the use of external database grid intensities and other methods. There are several factors that can contribute to this. In the program, pure grid mix is used for assessing the grid's intensity - indirect emissions (LCA - Life Cycle Assessment) were not included and the market instruments were not taken into the consideration (no residual mix). External databases may be using either direct emissions assessment or LCA in their calculations, which often is not clearly stated in the report containing the values. The values they are publishing may or may not be national residual mixes, which causes further differences between various databases. Finally, the big role in assessing a national grid intensity is energy source CO_2 emission factor values - the values used in external databases are most often not disclosed, so it becomes difficult to objectively compare the results from different databases.

An important thing introduced by CO_2 emission assessment software is the hourly-matching emission estimation procedure. This procedure is becoming more and more present in the reporting schemes and is expected to soon become a norm in the reporting standards. It is built on assumption that emissions should be accounted for in real-time, which also imposes the use of the hourly grid intensity factor. There are more and more large companies on the world's market that voluntarily are implementing the hourly scheme in reporting their emissions as a way to achieve 0 net carbon and be able to reliably prove it.

There does not exist one solution for a company to achieve 0 net carbon emissions. The market and norms are still not perfect and some changes and rapid progress is needed in order to meet the climate goals determined for the next 30 years. It is very difficult to assess the exact emissions, direct and indirect and limit them. The best approach, as described in GHG protocol is to divide the emissions by their origin, identify the sources of the emission in each company and implement programs that will eventually lead to the reduction of these emissions to 0. In the case of Scope 2 emissions, it is not so difficult anymore since nowadays we can easily choose the origin of the electricity we purchase. What we need to remember about is that different energy contracts may have various environmental impacts, and before signing a contract or buying a contractual instrument with intention of offsetting the emissions one needs to be aware of the features of such a contract. Achieving carbon neutrality as a whole will not be possible as long as there is any fraction of electricity in the grid that is not produced by sustainable energy sources. Companies should not only be subject to implementing green programs in order to fit in imposed restrictions but also should be encouraged and rewarded by taking voluntary actions towards environmentally-friendly schemes. Limitations on the domestic market may not happen for a long time, if ever. Because of this, the industrial market should be the main driver in the energy transition process.

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