Determination of the market-based CO_2 emission factor for Belgium

Addendum to the October 2021 report using a revised methodology

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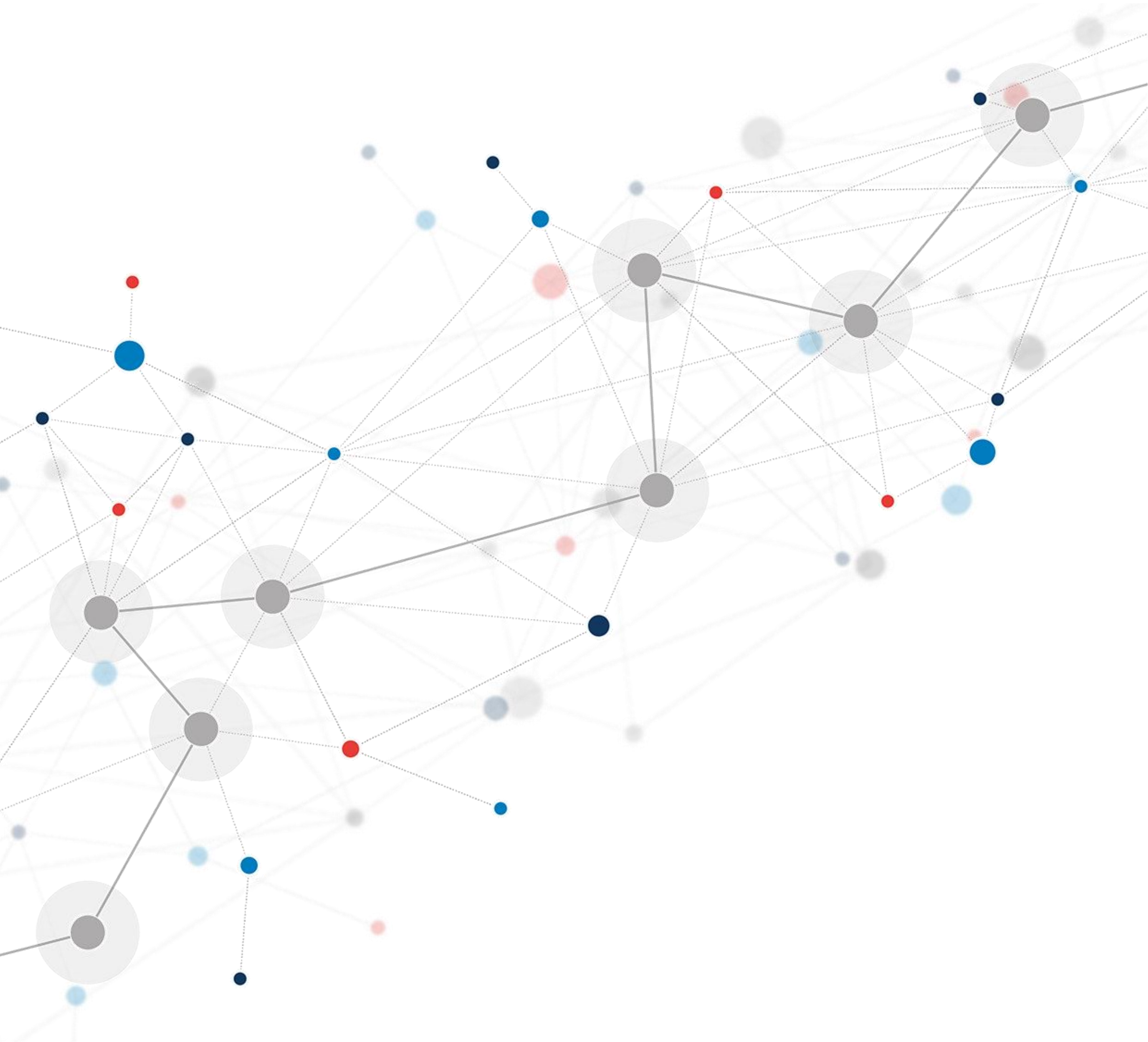

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Executive Summary

1 In October 2021, Compass Lexecon produced a report named “*Determination of the market-based CO_2 emission factor for Belgium*” for the Department of Economy, Science and Innovation (also known as EWI) of the Flemish region in Belgium. This report aimed at computing the market-based CO_2 emission factor for Belgium in the context of compensation for indirect EU ETS costs.

2 As requested by EWI, Compass Lexecon assessed this CO_2 emission factor for Belgium for year 2019 and by relying on a methodology based on the comparison of hourly power prices in two scenarios: (i) with the observed CO_2 prices (the actual scenario) and (ii) without CO_2 prices (the counterfactual scenario).

3 This methodology resulted in a market-based CO_2 emission factor of 0.55 tCO_2/MWh for Belgium for 2019. The methodology and results were validated by the Belgium energy regulator CREG.

4 Following discussions with the European Commission, EWI has asked Compass Lexecon to develop a revised methodology to compute the market-based CO_2 emission factor. Instead of relying on a counterfactual scenario, EWI asked Compass Lexecon to determine the CO_2 emission factor by assessing for each hour of 2019 the marginal technology and its corresponding CO_2 content, as mentioned in the 2020 European Commission Guidelines.

5 In this addendum to the October 2021 report, Compass Lexecon develops such a methodology in three steps:

a. Step 1 - We identify for each hour the modelled marginal technology in Belgium, based on our already existing 2019 backtesting exercise, which was already validated by the Belgian regulator

b. Step 2 - We derive the CO_2 content of the identified marginal technology for each hour, taking into account the specificities of CO_2-free technologies which are dispatched based on opportunity costs (e.g. dams and pumped-hydro storage)

c. Step 3 – We compute the average of the CO_2 content of the technologies identified as determining the electricity price for each hour in Belgium over the reference year (2019).

6 This methodology results in a market-based emission factor of **0.51 tCO_2/MWh** for Belgium, as detailed in the table below.

Table 1: Calculation of the annual market-based CO_2 emission factor for Belgium with a revised methodology

	Technology	% of 2019 hours when identified as marginal	Average **CO_2** content when marginal (tCO_2/MWh)
Belgian units	CCGT	11.6%	0.39
	Hydro	5.0%	0.60
	Steam gas	2.5%	0.43
	Gas turbine	1.0%	0.54
	Several technologies	0.2%	0.50
Foreign units		79.8%	0.52
	Annual market-based CO_2 emission factor		**0.51 tCO_2/MWh**

Source: Compass Lexecon analysis

Contents

1 Context and objectives of this addendum to the October 2021 report

The 2021 Compass Lexecon study assessing the market-based CO_2 emission factor for Belgium

7 In October 2021, Compass Lexecon produced a report named "*Determination of the market-based CO_2 emission factor for Belgium*" (referred as the 2021 study in this document) for the Department of Economy, Science and Innovation (also known as EWI) of the Flemish region in Belgium.[1] This report aimed at computing the CO_2 emission factor for Belgium in the context of compensation for indirect EU ETS costs,[2] as authorized by the Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2021 (referred as the 2020 Guidelines in this document).[3]

8 Among other variables, the compensation level payable per beneficiary for indirect ETS costs depends on a parameter which measures the extent to which the price of the electricity consumed by the beneficiary is influenced by CO_2 costs. This parameter is called the CO_2 emission factor and is measured in tCO_2/MWh.

9 Compared to the previous 2012 Guidelines,[4] the 2020 Guidelines now give the opportunity to Member States to establish the emission factor based on an alternative methodology, looking at the CO_2 content of the marginal technology determining the price on the electricity market:[5] this is referred as the market-based CO_2 emission factor.

10 In October 2021, as asked by EWI, Compass Lexecon assessed this market-based CO_2 emission factor for Belgium by relying on a methodology based on the comparison of hourly power prices in two scenarios: (i) with the observed CO_2 prices (the actual scenario) and (ii) without CO_2 prices (the counterfactual scenario). The final market-based CO_2 emission factor was then determined as:

$$CO2\ emission\ factor = \frac{Belgian\ annual\ power\ price\ with\ \mathrm{CO2}\ -\ Belgian\ annual\ power\ price\ without\ CO2}{Annual\ CO2\ prices}$$

11 Moreover, as specified by EWI, the 2021 study focused on the calculation of the CO_2 emission factor for the year 2019.

12 To perform this analysis, Compass Lexecon used its in-house European Power Market Dispatch Model that simulates the day-ahead power markets across Europe. The model also captures the impact of cross-border and import/export on price formation as it is run and optimised over all

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1 Available here

2 Indirect ETS costs referred to the increase of electricity prices following the introduction of the European Emissions Trading Scheme (EU ETS) in Europe. Indeed, electricity producers, covered by the EU ETS, must pay for each CO_2 emission they emit to produce electricity. This cost is reflected in their generation costs and ultimately in the electricity price which is paid by EU companies.

3 Available here

4 The 2012 Guidelines defined a methodology to compute an annual CO_2 emission factor based on macro indicators (annual CO_2 emission of the energy industry divided by the annual gross electricity generation from fossil fuels). However, this methodology has several drawbacks that tend to underestimate the CO_2 emission factor computed for Belgium, compared to neighbouring countries.

5 Point 15(11) of the 2020 Guidelines

European countries at the same time. The Compass Lexecon power dispatch model is implemented on the commercial modelling platform Plexos®, used worldwide by utilities, regulators, transmission system operators ("TSOs") and consulting firms, relying on data and assumptions based on publicly available sources (in particular from ENTSO-E) or based on Compass Lexecon proprietary databases.

13 This methodology resulted in a market-based CO_2 emission factor of 0.55 tCO_2/MWh for Belgium for 2019.

14 Moreover, this analysis and report were submitted to the Belgium energy regulator CREG in January 2022. After analysis and a public consultation, the regulator validated the approach and the results.[6]

Context for this addendum report and the revised methodology

15 Following discussions with the European Commission, EWI has asked Compass Lexecon to develop a revised methodology to compute the market-based CO_2 emission factor. Instead of relying on a counterfactual scenario, EWI asked Compass Lexecon to determine the CO_2 emission factor by assessing for each hour of 2019 the marginal technology and its corresponding CO_2 content, as mentioned in the 2020 European Commission Guidelines.

16 The application of the revised methodology is structured in four different steps, which will be further described in the following sections:

a. Presentation of the revised methodology

b. Identification of the marginal technology for each hour

c. Identification of the CO_2 content for each technology

d. Calculation of the final CO_2 emission factor.

6 Decision (B)2364 available here

2 Presentation of the revised methodology

17 In this section, we present our revised methodology to compute the market-based CO_2 emission factor.

18 According to the 2020 Guidelines, the market-based CO_2 emission factor shall be established "*based on a study of the CO_2 content of the actual margin setting technology in the electricity market. Such a notification of a market-based* CO_2 *emission factor must demonstrate the appropriateness of the retained market-based* CO_2 *emission factor based on a model of the electrical system simulating price formation and observed data on the margin setting technology over the entire year t-1 (including the hours when imports were margin setting)*". [7]

19 We are not aware of any actual data assessing the marginal technology for Belgium for 2019.

20 Instead, and as advised by the 2020 Guidelines, we rely on our power market dispatch model to identify for each hour the modelled marginal technology. We rely exactly on the same power market dispatch model as in our 2021 study. In particular, we use the same results regarding the backtesting exercise for the year 2019, as further described in the next section. This dispatch model has been already validated by the Belgian regulator CREG.

21 We then develop a methodology in three steps:

a. Step 1 - We identify for each hour the modelled marginal technology in Belgium, based on our 2019 backtesting exercise

b. Step 2 - We derive the CO_2 content of the identified marginal technology for each hour, taking into account the specificities of CO_2-free technologies which are dispatched based on opportunity costs (e.g. dams and pumped-hydro storage)

c. Step 3 – We compute the average of the CO_2 content of the technologies identified as determining the electricity price for each hour in Belgium over the reference year (2019).

22 The next sections present in turn our work and findings on each of these steps.

[7] Point 15(11) of the 2020 Guidelines

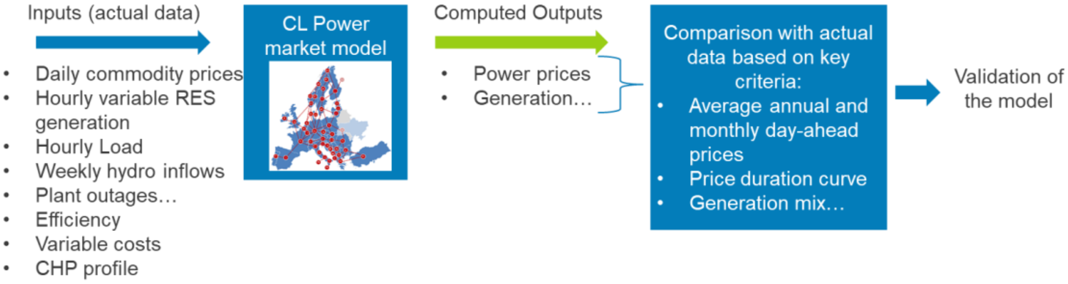
3 Step 1 – Identification of the marginal technology in Belgium for each hour in 2019

23 In this first step, we identify for each hour the marginal technology in Belgium based on our 2019 dispatch modelling.

Our 2019 dispatch modelling as a robust proxy to identify actual marginal technologies

24 In order to identify the marginal technology for Belgium for each hour, we rely on our already existing 2019 backtesting exercise. This backtesting exercise was presented in our 2021 report[8] and is briefly summarised below. Please note that we do not run any new simulations for this revised methodology: we rely on already existing simulations (and already validated by the Belgian regulator), from which we have extracted new outputs (namely the marginal technology).

Figure 1: Overview of the backtesting methodology and validation of the power market dispatch model



Source: Compass Lexecon

25 Based on our in-house European Power Market Dispatch Model that simulates the day-ahead power markets across Europe, we have simulated prices over a historic period (2019 for this study) that we compared with actual prices over the same period. The lower the difference the greater comfort we can draw that our model replicates correctly actual day-ahead prices.

26 For 2019, results showed that for Belgium but also for neighbouring countries, annual differences between actual and modelled prices were well within the 5% margin often considered to validate a power market dispatch model based on international experience. On average, the difference between actual and modelled prices was around 0.80€/MWh for Belgium, i.e. a 2% error margin.

27 Thus, the backtesting exercise for the year 2019 confirms the accuracy of our power market dispatch model to replicate day-ahead prices. **Our 2019 modelling is therefore a robust proxy to identify the actual marginal technology for each hour**.

[8] See section 3 of the 2021 study

Identification of the marginal technology as a direct output of our dispatch model

28 Based on our 2019 backtesting exercise, we can easily identify the marginal technology given that it is a direct output of our dispatch model. Indeed, in addition to the hourly day-ahead prices, our dispatch model indicates which technology sets the price in Belgium for each hour. Moreover, given that our dispatch model is run at a unit basis, marginality is even computed at a unit-based level.[9]

29 The identified marginal unit can either be in Belgium or in a neighbouring country if there is a price convergence with Belgium during this hour.

Results of marginal technology in Belgium for 2019

30 Marginality by technology in Belgium in 2019 is provided in the Table 2 and Figure 2 below.

Table 2: Marginality by technology in 2019 in Belgium

	Technology	% of 2019 hours when identified as marginal
Belgian units	**CCGT**	**11.6%**
	Hydro	**5.0%**
	Steam gas	**2.5%**
	Gas turbine	**1.0%**
	Several technologies[10]	**0.2%**
Foreign units	**Total foreign units**	**79.8%**
	of which CCGT	*17.8%*
	of which Coal	*7.5%*
	of which Lignite	*8.8%*
	of which Nuclear	*11.6%*
	of which Hydro	*18.0%*
	of which Other technologies[11]	*5.5%*
	of which Several technologies	*10.5%*

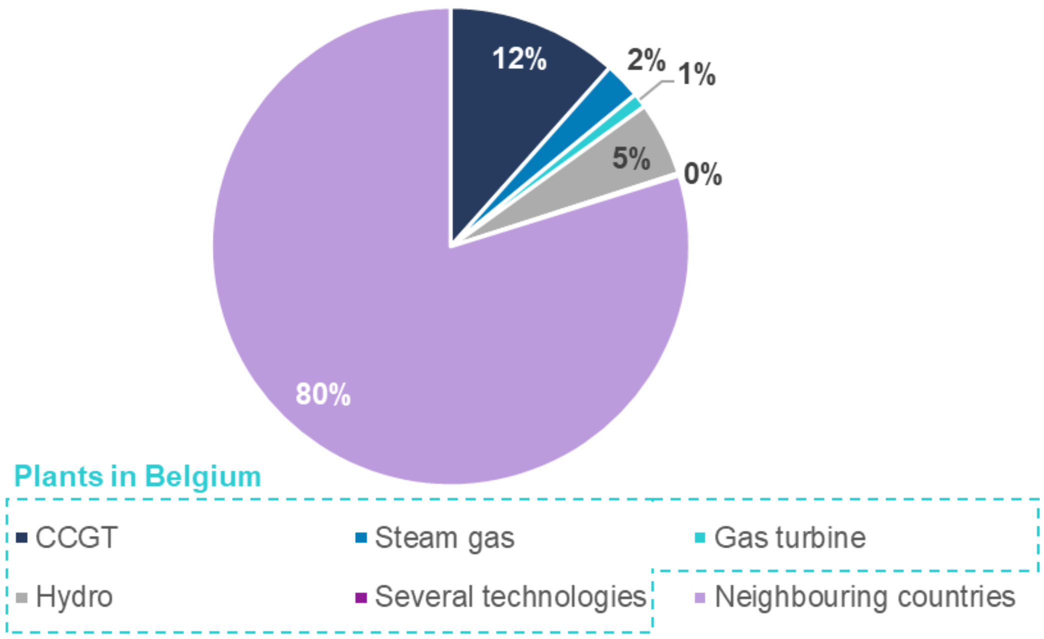
Source: Compass Lexecon modelling and analysis

9 This will give more precise results during step 2 when computing the CO_2 content of each marginal unit given that this CO_2 content depends on unit efficiency.

10 This category includes:
- Hours when at least two different thermal technologies are identified to be marginal (for instance one CCGT and one coal plant)
- Hours when (i) a hydro unit is identified to be marginal and (ii) a thermal unit is identified to be marginal

11 The "other" category mainly includes units which burn natural gas but which are not a CCGT, ie steam gas and gas turbine units.

Figure 2: Marginality by technology in Belgium in 2019



Source: Compass Lexecon modelling and analysis

31 Given the high price convergence with neighbouring countries, a neighbouring plant is assessed to be marginal in Belgium during 80% of 2019 hours. Among Belgian plants, CCGT is the most common marginal technology (12%), followed by pumped-hydro storage (5%).

32 When a foreign plant is marginal, it is mostly CCGT, hydro (mainly large dams and pumped-hydro storage) and nuclear.

4 Step 2 – Determination of the CO_2 content for each marginal technology

33 In this second step, we determine the CO_2 content of each marginal technology. This CO_2 content is determined as the amount of CO_2 (per MWh) reflected in the bids that plants submit on the day-ahead market. As discussed below, this CO_2 content can be either explicit as for thermal units (ie. thermal units actually emit CO_2 whose cost is reflected in their bids) or implicit as for energy-constraint units (eg. pumped storage units), which do not emit CO_2 but do factor some CO_2 costs in their bids.

34 Given that the goal of the study is to compute a market-based emission factor, which measures the extent to which the price of the electricity is influenced by CO_2 costs, it is relevant to consider the amount of CO_2 reflected in the bids, even if that CO_2 is not actually emitted by the plant.

Determination of the CO_2 content for thermal units

35 In a competitive market, economic theory indicates that thermal plants should offer their generation at their short-run marginal cost ("SRMC"). As a result, the CO_2 content of a thermal plant can be directly linked with the SRMC formula and can be computed as:

$$CO2\ content\ for\ a\ thermal\ plant = \frac{Fuel\ CO2\ emission\ factor}{Plant\ efficiency}$$

36 In our calculation, efficiency data come from Compass Lexecon database, which was built based on third-party sources (Platts, ENTSO-E), market intelligence and which is regularly updated based on latest announcements from plants operators, utilities and regulators.

37 The CO_2 emission factor of fuels is based on standard values found in the literature, for instance in the ENTSO-E database[12] (e.g. 0.185 tCO_2/MWh_{HHV} for gas, 0.338 tCO_2/MWh for coal…).

38 This methodology has been applied both for domestic and foreign thermal units.

Determination of the CO_2 content for units with storage capability

39 Pumped hydro and large dams do not emit any CO_2. However, their bids in the day-ahead market often include some CO_2 content as explained below.

40 Indeed, due to a limited storage, the operator of such energy-constrained technology has to carefully manage the quantity of available fuel (for instance water) within the day/month/year to optimise its revenues. For instance, it may decide to reduce the generation during hours with low prices, even if prices are higher than the variable costs, in order to save fuel and to use it during hours with higher prices instead.

41 These energy-constrained technologies participate in the day-ahead auction on the basis not of their variable production cost, but of their opportunity cost, which reflects the profit they forego by not being able to produce in another hour due to limited water. These opportunity costs are often correlated with the SRMC of thermal units for which hydropower plants are substituted.

12 See for instance in the input data used for the ERAA 2021 edition available here (sheet "Thermal Properties").

42 As a result, whenever hydro with limited storage (dams, pumped hydro) is identified as marginal, power prices paid by consumers include a non-zero CO_2 content.

43 In our exercise, we reflect this concept by attributing a CO_2 content to hydro with limited storage when marginal. [13] More precisely, whenever a pumped-hydro or dam unit is assessed to be marginal (in Belgium or in neighbouring countries), we identify the thermal technology with the closest SRMC (in €/MWh) compared to hydro opportunity costs. We use the CO_2 content of this identified thermal technology as the hydro CO_2 content.

- For instance, if hydro opportunity costs are equal to 50€/MWh, hydro tends to replace a thermal unit with SRMC close to 50€/MWh
- We suggest identifying this thermal unit as marginal and to use its CO_2 content instead

44 As described in the point 2.14 in our 2021 study, the French nuclear fleet has also some limited storage (there is a limited amount of uranium that a reactor can use between two refuelling outages). The concept of opportunity costs can also apply to French nuclear units – in this case, French nuclear plant output is dispatched and offered on the market based on an opportunity cost bidding strategy (and not based on its variable costs only), which can include some CO_2 content, as for hydro. However, as a conservative simplifying assumption as asked by EWI, we do not consider this specificity of French nuclear units and we assume a CO_2 content of zero for nuclear.

CO_2 content results for 2019

45 The average CO_2 content for each marginal technology in Belgium is provided in the table below.

46 The CO_2 content is lower for units using gas instead of coal or lignite because gas emits less CO_2 per MWh. Among gas units, the CO_2 content is lower for more efficient units (i.e. CCGTs) and higher for steam gas and gas turbines units, which are less efficient than CCGTs.

47 When marginal, hydro units have an average CO_2 content of 0.6 tCO_2/MWh, reflecting the fact that they tend to substitute to both gas units and coal units.

48 The CO_2 content of all marginal foreign units (0.52 tCO_2/MWh) is slightly higher than the CO_2 content of CCGTs because coal and lignite units are sometimes marginal in neighbouring countries.

[13] A CO2 content of zero is assumed when run-of-river hydro is marginal. However, this technology is not identified as marginal in Belgium in 2019.

Table 3: Average CO_2 content for each marginal technology in Belgium in 2019

	Technology	Average CO_2 content when marginal (tCO_2/MWh)
Belgian units	**CCGT**[14]	**0.39**
	Hydro	**0.60**
	Steam gas	**0.43**
	Gas turbine	**0.54**
	Several technologies[15]	**0.50**
Foreign units	**Foreign units**	**0.52**
	of which CCGT	*0.37*
	of which Coal	*0.87*
	of which Lignite	*1.08*
	of which Nuclear	*0*
	of which Hydro	*0.61*
	of which Other technologies	*0.49*
	of which Several technologies	*0.50*

Source: Compass Lexecon analysis

14 Average CO_2 content for CCGT can slightly differ between Belgian and foreign units (0.39 vs. 0.37) because of different efficiencies across Europe.

15 For hours where at least two different thermal units are identified as marginal, we attribute the average CO_2 content of those technologies. For hours when a hydro power plant and a thermal unit are identified as marginal, the study attributes the CO_2 content of the thermal unit.

5 Step 3 - Calculation of the final market-based CO_2 emission factor with the revised methodology

49 Once we have determined (i) the marginality share of each technology in 2019 and (ii) the average CO_2 content of these marginal technologies, we can compute the annual market-based CO_2 emission factor as the weighted average of both values, as detailed below in Table 4 and Figure 3.

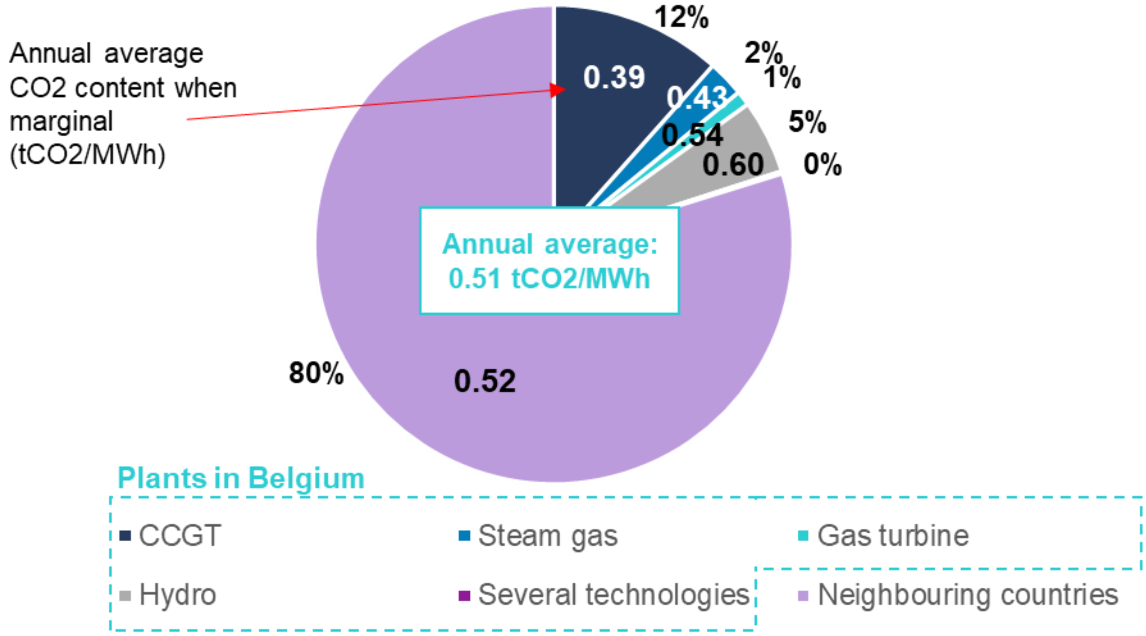
50 **The annual average results in a market-based emission factor of 0.51 tCO_2/MWh for Belgium in 2019.**

Table 4: Calculation of the annual market-based CO_2 emission factor for Belgium with the revised methodology

	Technology	% of 2019 hours when identified as marginal	Average CO_2 content when marginal (tCO_2/MWh)
Belgian units	CCGT	11.6%	0.39
	Hydro	5.0%	0.60
	Steam gas	2.5%	0.43
	Gas turbine	1.0%	0.54
	Several technologies	0.2%	0.50
Foreign units		79.8%	0.52
	Annual market-based CO_2 emission factor		**0.51 tCO_2/MWh**

Source: Compass Lexecon analysis

Figure 3: Market-based CO_2 emission factor for Belgium with the revised methodology



Source: Compass Lexecon analysis

51 In our October 2021 study using a different counterfactual methodology, we found an emission factor of 0.55 tCO_2/MWh. The main difference between the emission factor estimates in the two studies can be attributed to the treatment of the French nuclear units – which as explained above are assumed to have a zero CO_2 content as a conservative simplifying assumption in the revised methodology used in this addendum report.

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