Master thesis on Competition and Market Regulation
Barcelona Graduate School of Economics

Green Agreement in the Electricity Market: An ex-post evaluation of the 2013 Dutch Coal Power Plants Closure Agreement

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June 2021

Barcelona GSE
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We would like to thank Natalia Fabra for her inputs on how electricity markets work and for her suggestions on the Stated Preference Analysis.

We would also like to thank Javier Biscarri for his precious help and suggestions on the econometrics applied to time-series.

Finally, we would like to thank Thomas Stoerk for the insights he provided on the evaluation of CO2 emission reductions.

We would also like to thank our family, friends and partners for the moral support.

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Abstract

There has been much theoretical discussion on whether Green Agreements can be a cost efficient means of improving the sustainability of products. However, no empirical studies have been done on what the cost and benefits of past Green Agreements have been. In order to provide a substantive contribution to this discussion, we have undertaken an ex-post analysis of a 2013 agreement in the Netherlands to close five aging coal power plants in 2016 and 2017. First, we evaluate the Authority for Consumers and Markets's (ACM) assumption that the plant closures would result in an increase of the Dutch wholesale electricity price in the Netherlands by undertaking a before-and-after analysis. Second, we examine how the ACM quantification of the benefits deriving from emissions reductions would have changed if it used the same methodology a year after the plants closed (in mid-2018) and if it used an alternative evaluation technique based on estimating consumers' willingness to pay for green electricity. Our findings indicate that the ACM evaluation was likely incorrect to oppose the agreement to close the coal power plants. Our conclusion suggests that those working on ex-ante assessments of Green Agreements should recognise that the environmental policy approach of their government can be extremely volatile and alter their assessments.

Keywords: Green Agreements, Green Electricity, Stated Preferences, Shadow Prices, Emissions, Ex-Post Analysis

1 Introduction

Over the past few years, climate change has been increasingly recognized as an existential crisis. In this context, electricity production accounts roughly for 20% of total greenhouse gasses (GHG) emissions in the European Union (EU) (EEA (2021)). As such, the shift from fossil fuels electricity generation to renewables is high on the European political agenda (See EC (2019)).

The transition to 'greener' means of electricity production does not seem achievable via the market itself. Indeed, there is significant scope for market failures, which result in insufficient measures being taken. On the demand side, market failures include hyperbolic discounting of future environmental damage[1], as well as an unwillingness to pay for environmental or social costs unless all other consumers pay an equivalent amount (ICC (2020); Schinkel and Treuren (2021)). On the supply side, market failures include the so-called 'first-mover dis-advantage': no single firm would unilaterally close old polluting power stations and make significant investments in sustainable production if rivals continue to supply electricity with polluting power stations at a cheaper cost (Dolmans (2020)). Already Coase (1960) proposed a course of actions to eliminate the inefficiencies associated with externalities through bargaining among affected parties - the voluntary Coasian bargaining. Prerequisites of such a bargaining process are a clear definition of property rights, irrespective to whom the rights are assigned (e.g. polluters or victims), and zero or negligible transaction costs (Coase (1959); Coase (1960)). However, a Coasian solution does not appear to be feasible due to the outstanding number of people impacted by climate change, which make the transaction costs for such bargaining extremely high (Choy and Ho (2018)).

Due to market failures, government have taken actions to reduce GHG emissions in the electricity sector. There exists a wide variety of interventions to choose from, ranging from cap-and-trade schemes (such as the European Union Emission Trading System)[2],

[1] This is the phenomenon where consumers have an insufficient willingness to pay for the shift to renewable energy production due to placing a low value on averting a calamity that is to occur in the future. *See:* Time Discounting, Behaviouraleconomics.com (2019), at: https://www.behavioraleconomics.com/resources/mini-encyclopedia-of-be/time-temporal-discounting/

[2] At the EU-level, the European Union Emission Trading System (EU ETS) has been implemented. It aims at reducing the aggregate GHG emissions in several sectors (including the energy sector) by creating a

carbon taxation (such as Carbon Prices Floors), subsidisation of renewable energy production, as well as rules for responsible sourcing and support for innovation (Schinkel and Treuren (2021); ICC (2020)). However, even where regulation might be efficient, it might not be effective because of political compromises, jurisdictional and/or geographical limitations, insufficient implementation or the administrative burdens involved (Pacheco et al. (2020); Nowag (2021)).

Against this backdrop, Green Agreements, defined as private agreements between competitors aimed at reducing GHG emissions, have been recently seen as a rapid, efficient, and less costly option to foster the green transition (ACM (2020a)). The 'Green Antitrust Movement' claims that conflicts between the market and the environment can be solved via 'Green Agreements' between private undertakings. The movement advocates exemptions from the cartel law (under Article 101(3) of the Treaty on the Functioning of the European Union (TFEU)) for certain agreements that aim at increasing sustainability (Schinkel and Treuren (2021); Dolmans (2020); Holmes (2020); Brook (2019); Monti (2020); Kingston (2019)). Green Agreements between owners of power plants could be particularly useful in assisting the decarbonisation of the electricity sector. Indeed, parties would be more willing to withdraw inefficient power plants from the market early if their competitors also agreed to do likewise thus neutralising the first-mover disadvantage. Given that capacity reduction agreements between competitors can potentially have adverse effects on competition (resulting in price increase), regulators will need to decide if the adverse effects are justified by the benefit of the reduction in emissions.

For policy makers and regulators considering whether to allow a proposed Green Agreement between power plant owners, some studies have been published on the economic and legal theories of Green Agreements, as well as studies on the possible benefits of future coal plant closures. Scholars like Schinkel and Spiegel (2016), Martinez et al. (2019), and Schinkel and Toth (2019) have explored the implications of Green Agreements on sustainability from a microeconomics theoretical perspective. These studies emphasise the risk of greenwashing in the context of markets for differentiated products. They find that allowing firms to coordinate their sustainability efforts leads to the low-

limited number of tradable allowances – the cap. However, the EU ETS has been characterised by a surplus of allowances, which in turn resulted in persistently low prices and reduced incentives for low-carbon investment.

est sustainability levels and high prices. Conversely, allowing firms to coordinate their output levels (or prices) but not their investments (production cartel) leads to higher investments in sustainability and may even benefit consumers. However, these studies have limited applicability to decisions about Green Agreements in electricity markets, given that electricity is a homogeneous product.

There also exists a literature on the benefits of coal-fired power plants closure in the Netherlands. This includes reports which estimate the effects of future coal plant closures, as well as papers that consider future policy options for reducing emissions given past government interventions related to coal plants (CE-Delft (2019); FrontierEconomics (2016); Akerboom et al. (2020); Mulder and Pangan (2017)). However, these do not examine the actual ex-post impact of using Green Agreements to close coal plants in any significant details.

While there is at least one ex-post study of a Green Agreement deemed to be anticompetitive - the ACM ex-post analysis of the 2015 decision to block the ‘Chicken of Tomorrow’ agreement - this analysis is based on changes in the market given that the agreement did not take place (ACM (2020b)). The current literature is, thus, lacking empirical studies that examine benefits and costs of past Green Agreements in the electricity sector from an ex-post perspective.

This paper, in turn, seeks to fill this gap by undertaking an ex-post evaluation of the Dutch Authority for Consumers and Markets’ (ACM) 2013 assessment of an agreement between energy producers in the Netherlands for the early closure of five aging coal-fired power plants (ACM (2013)). The ACM opposed the agreement, but the Dutch Ministry of Economic Affairs nevertheless ensured that the agreement was implemented. Following the agreement, Mulder and Kloosterhuis (2015) - two ACM economists that worked on the case - explained in details the methodology used for the assessment. Nonetheless, the authors purely cover the ex-ante analysis and their paper was published before the closures actually occurred.

This case offers an exceptional opportunity to analyse a Green Agreement that took place even if it was deemed to be anticompetitive. This, in turn, allows us to scrutinise the general assumptions that the regulator made in its ex-ante analysis, in light of empirical evidence on the agreements effects and changes to government policy following the decision. In addition to being relevant to those evaluating proposed green agreements in the electricity sector, our findings could be relevant to agreements in sectors with homogenous goods that are regulated under the EU ETS system (e.g. oil refinery and mineral industries).

This paper is structured as follows. In Section 2, we present a briefing on the Energy Accord case dealt with by the ACM. In Section 3, we empirically analyse the price effect of the coal-fired power plant closure. In Section 4, we reconsider the ACM evaluation between the estimated price effect and reduction in emissions. In particular, we compare the ACM valuation of the benefit from the reduction in emissions in 2013 to how it would have evaluated the closures at a later date. We also provide a possible alternative method that the ACM could have used to estimate the cost of GHG emissions, namely a Stated Preferences approach. Section 5 concludes.

2 Background: Dutch Coal Plant Closures

In 2013, an agreement was brokered between 47 signatories in the Netherlands (including the Dutch Government), called the SER Energieakkoord (or Energy Accord). This agreement contained several initiatives aimed at improving energy efficiency and increasing the share of electricity produced from renewable energy sources (SER (2013)). One aspect of the Energy Accord was an agreement with major energy producers to close down five aging coal-fired electricity plants five years ahead of the regulated schedule (later referred as the Closure Agreement)[3]. Three of the coal plants were to be closed in January 2016 and two in July 2017, even though they were expected to continue to be commercially viable until 2022. The Closure Agreement would have resulted in a reduction in GHG emissions from 2016 to 2021, compared to a scenario where such an agreement did not occur.

The five coal power plants accounted for approximately 10% of total electricity capacity in the Netherlands at the time. Therefore, the Closure Agreement could have had an

[3]The five coal-fired power plants are: Gelderland held by GdF, Borssele held by Delta, Amer-8 held by RWE, Maasvlakte 1 and 2 held by E.ON (ACM (2013)

adverse effect on competition, manifesting itself in a wholesale electricity price increase. The Closure Agreement was thus referred to the ACM for its informal opinion on whether it was anti-competitive and in breach with Article 101 of the TFEU (ACM (2013)). The ACM relied on analysis by the Dutch Energy Research Institute (ECN), which modelled the expected emissions reduction as well as the expected increase in electricity prices resulting from the Closure Agreement. In its report, the ECN estimated that the Closure Agreement would result in €75m increase in the average annual cost of wholesale price of electricity, while also resulting in the reduction of 1.5 kton of nitrogen oxides (NO_x), 2.0 kton of sulphur dioxide (SO_2), 0.1 kton of particles (also referred to as PM_{10}) and 4,700 kton of carbon dioxide (CO_2) (ECN (2013)). The ACM calculated that the benefit from the annual reductions in NO_x, SO_2 and PM_{10} should be valued at approximately €30m. The ACM, however, did not consider there to be any benefit from the annual 4,700 kton reduction in CO_2, due to the 'Waterbed Effect' (explained further in Section 4.3).

The ACM therefore regarded the benefits of the Closure Agreement (the annual reduction in NO_x, SO_2 and PM_{10}, valued at approximately €30m) to be insufficient to offset the drawbacks to Dutch electricity buyers (the annual €75m increase in wholesale electricity prices). As a result, the ACM concluded that the Closure Agreement fell within the scope of Article 101 and did not fall within the exception set out in Article 101(3). However, despite the ACM's conclusion, the Ministry of Economic Affairs ensured that the Closure Agreement was implemented, and the five coal plants all closed in 2016 and 2017 as specified in the Closure Agreement. Hence, these plant closures represent a unique opportunity to undertake an ex-post evaluation of a Green Agreement deemed to be anti-competitive by a national competition authority.

3 Empirical assessment of the price effect

We first empirically assess the effect of the Closure Agreement on Dutch wholesale electricity prices. Our study focuses on the period from January 2010 to December 2020. This includes the closure of the coal-fired power plants, while also allowing for a window of time where the coal-fired power plants were still active.

3.1 Model and Data

In the Netherlands, wholesale electricity prices are set in the Day Ahead Market (APX Market) where on a daily basis, electricity producers and retailers submit 24 hourly bids where they specify price-quantity pairs at which they are willing to sell and buy at a given hour of the following day. The market operator orders the individual bids to construct the aggregate supply and demand functions for every hour, and determines the market clearing price and quantities allocated to each bidder.

In our data, we observe the daily average market clearing price for the period spanning from January 2010 to December 2020. Figure 1 - which sets out the evolution of wholesale prices over the sample period - shows that electricity prices are highly volatile due to changes in demand and supply conditions. Movements in demand show strong seasonal components (e.g., winter-summer, weekday-weekend), and supply conditions vary with the availability of renewable resources and with changes in input prices such as the price of coal and gas.

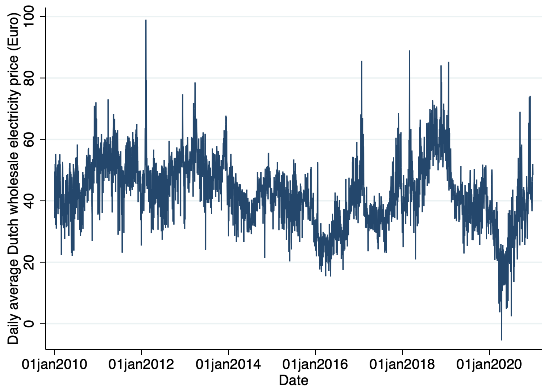

Figure 1: Evolution of the Dutch Wholesale Electricity Price
Source of Data: Bloomberg

In order to estimate the impact of the closure of the coal-fired power plants on wholesale electricity prices, we employ a multivariate approach. This refers to a more elaborate version of the basic before-and-after approach. The basic approach mainly relies on the historical time series of the wholesale electricity prices to compare prices before and after the closure of the power plants. The raw form of the before-and-after methodology implicitly assumes that market conditions are unchanged. However, if demand and supply conditions vary, the methodology is bound to be incorrect to at least some extent (Davis and Garcés (2010)).

To address this criticism we undertake a reduced-form regression of the wholesale electricity price in levels on demand and cost shifters that affect the electricity price, but that are not affected by the decision to close the power plants. We also include two dummy variables to account for the closures of the coal power plants, respectively in January 2016 and July 2017. The dummies aim to capture the effect of the Closure Agreement on the electricity wholesale price.

Moreover, we include three types of fixed effects: the day of the week, the month and the year[4]. We include the day of the week fixed effect in order to control for weekly patterns (e.g. households may demand more electricity over the weekend compared to weekdays). The monthly fixed effect is included to control for the seasonality of electricity prices, as well as potential monthly trends. The yearly fixed effect is included in order to capture exogenous shocks for which we are not controlling for. For example, in 2020, the pandemic crisis (which can be considered an exogenous shock) may have had an impact on electricity prices. The yearly fixed effect should be capturing this effect.

It follows that the main specification is as below:

$$P_t = \beta_0 + \beta_1 Closure1_t + \beta_2 Closure2_t + \beta_3 X_t + \beta_4 Z_t + \omega_t + \varepsilon_t$$

where $\mathrm{P_t}$ is the Dutch average daily wholesale electricity price. X stands for the demand shifters and Z stands for the supply shifters. Omega is a vector of fixed effects and epsilon is the error term. 'Closure1' and 'Closure2' refer to the two dummies that should capture the effect of the Closure Agreement on electricity prices. In the following subsections we discuss the demand and supply shifters included in the model.

3.1.1 Demand Shifters

On the demand side, we consider the daily average temperature in the Netherlands as the main factor moving demand (Fabra and Reguant (2014); Paraschiv et al. (2014)). Indeed, electricity demand is expected to be higher during cold seasons compared to hot ones.

[4]Similar approaches have been taken by Mulder and Scholtens (2013), Fabra and Reguant (2014), Clo et al. (2015)

This is in line with households using heating devices more when the air-temperature is low. Furthermore, when the temperature is high, we expect demand to be lower especially given the low usage of air conditioning in the Netherlands (only 11% of households have air-conditioning) (Randazzo et al. (2020)). The data on air-temperature is based on a daily average air-temperature across a number of locations. We use data published by the Dutch meteorological institute (KNMI) for 10 main stations[5]. Moreover, we control for the number of hours of sunlight in a day. Households are expected to demand more electricity when the number of hours of sunlight in a day is lower (e.g. in winter days) (Bushnell and Novan (2018)).

3.1.2 Supply Shifters

The Merit-Order Curve is key to understand the electricity spot price building mechanism. It can be interpreted as the sorted marginal cost curve of electricity production (Paraschiv (2013)). During off-peak hours, base-load must-run facilities (nuclear and lignite-fired power plants) are mainly used in production. By contrast, during phases of high demand, power plants with high flexibility and high marginal costs of production such as gas- and oil-fired power plants are also used.

Renewable energy sources such as wind and photovoltaic power plants (e.g. solar power) have an additional impact on the Merit-Order Curve. Electricity supply from renewable energy sources has the lowest marginal costs of production, which is close to zero. Given that energy generated from renewables is always directly fed into the grid, any increase in renewable energy shifts the merit order curve to the right (Clo et al. (2015). This, in turn, leads to lower electricity prices.

Given these important considerations, on the supply side we take into account the prices of commodities (gas, oil and coal). Indeed, the marginal cost of thermal plants depends mainly on the input price. Moreover, we include wind speed and number of hours of sunlight in a day, since the latter control for the level of energy coming from the two main renewable sources in the Netherlands: windmills and solar panels[6]. We also control

[5]The stations included are De Kooy, Schiphol, De Bilt, Leeuwarden, Eelde, Twenthe, Vlissingen, Rotterdam, Eindhoven and Maastricht

[6]Wind turbines and solar panels accounts for roughly 69% of total renewable electricity and heat produced in the Netherlands.*See* IEA at `https://www.iea.org/countries/the-netherlands`

for the wind speed squared as windmills have to be turned off when the wind is very strong. The resulting reduction of available renewable capacity is expected to increase electricity prices (Fabra and Reguant (2014)). The data on wind speed and number of hours of sunlight is based on a daily average measured across a number of locations. We use data published by the Dutch meteorological institute (KNMI) for 10 main stations as per the air-temperature. Moreover, on the supply side we control for the price of CO_2 European Allowances (EUA). Indeed, under the EU ETS system, thermal plants making use of fossil fuels for electricity production face higher marginal costs given that carbon pollution has a price attached to it (Fabra and Reguant (2014); Paraschiv et al. (2014)).

Finally, because the Dutch electricity market is closely linked to the German market, we include the level of wind speed in Germany following the approach suggested by Mulder and Scholtens (2013). There is a large amount of windmills installed in Germany and the Netherlands imports significant amounts of green electricity from the former. We, therefore, use the data from the German meteorological institute (DWD) referring to five different locations and we take the daily average wind speed across the five selected locations[7].

Table A1 and A2 in Appendix A provides descriptive statistics of the variables discussed.

3.2 Results using Ordinary Least Square (OLS)

Table 1 outlines our estimates using OLS estimation of the impact of the Closure Agreement on wholesale Dutch electricity prices. Column (1) only shows the effect of the supply and demand shifters on Dutch electricity prices without including either fixed effects nor the dummies reflecting the coal-fired power plants closure. Column (2) displays the regression results without including fixed effects. Columns (3), (4) and (5) report the results with the progressive inclusion of a higher number of fixed effects. The main regression results are shown in column (5) where all the relevant fixed effects are included. Below we refer to the results shown in column (5). All the supply shifters enter with the expected sign and are significant, except for the level of wind speed in Germany and

[7]The locations included are: Berlin, Kiel, Hannover, Düsseldorf and München

Table 1: Price Effect: OLS Regression Results

	(1)	(2)	(3)	(4)	(5)
Closure 1		-0.599	-1.536**	-1.618**	-1.761***
		(-1.59)	(-2.81)	(-2.95)	(-3.78)
Closure 2		-0.333	-1.078*	-1.698***	-1.735***
		(-1.01)	(-2.50)	(-3.71)	(-4.54)
Gas	0.443***	0.444***	0.393***	0.425***	0.429***
	(40.95)	(38.56)	(22.58)	(22.17)	(26.14)
Oil	0.0147	0.00793	0.0463**	0.0399*	0.0392**
	(1.73)	(0.84)	(2.98)	(2.47)	(2.81)
Coal	0.155***	0.157***	0.103***	0.0794***	0.0751***
	(18.37)	(18.16)	(4.61)	(3.50)	(3.87)
EUA	0.486***	0.485***	0.950***	0.966***	0.966***
	(31.87)	(25.93)	(15.65)	(16.48)	(19.31)
Temperature	-0.222***	-0.220***	-0.247***	-0.412***	-0.409***
	(-9.53)	(-8.97)	(-10.13)	(-9.34)	(-10.33)
Wind Speed	-1.355***	-1.347***	-1.427***	-1.373***	-1.273***
	(-5.90)	(-5.85)	(-6.24)	(-6.04)	(-6.38)
Wind Speed Squared	0.0444*	0.0432*	0.0560**	0.0603**	0.0527**
	(2.13)	(2.07)	(2.68)	(2.84)	(2.74)
Wind Speed Germany	-0.00475	-0.00459	-0.00455	-0.00767	-0.00831
	(-0.62)	(-0.59)	(-0.65)	(-1.06)	(-1.50)
Hours of Sun	0.0441	0.0426	0.0273	0.0273	0.0182
	(1.31)	(1.25)	(0.85)	(0.85)	(0.69)
Constant	8.755***	9.119***	0.0464	-0.304	-7.287***
	(10.35)	(10.09)	(0.03)	(-0.18)	(-5.05)
N	4018	4018	4018	4018	4018
Yearly FE	N	N	Y	Y	Y
Monthly FE	N	N	N	Y	Y
Day of Week FE	N	N	N	N	Y
Avg. Electricity Price	43.28				

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

the number of hours of sunlight. The commodities' prices are expected to increase the price of electricity and this is confirmed by the results. Moreover, the coefficient of the EUA is positive and significant. This is in line with expectations, given that the EU allowances increase the price of electricity produced by burning fossil fuels. The level of wind speed, as expected, decreases the electricity prices. The squared level of wind speed increases the price as expected, since when the wind is too strong windmills have to shut down, reducing the amount of available renewables. Similarly, the level of wind speed in Germany is decreasing the level of Dutch electricity price, as expected. However, the coefficient of wind speed in Germany is not significant. Moreover, the number of hours of sun-light is not significant. This might be explained by the still low usage of solar panels in the Netherlands. Alternatively, it can also be that Dutch electricity demand is not significantly affected by the hours of sun in a day (as explained in the previous section the hours of sun in day is both a demand and a supply shifter). Finally, air-temperature decreases the price and it is significant. This is consistent with electricity demand being higher during winter days and lower during the summer.

Concerning the two dummies, the Closure Agreement seems to have a significant negative impact on the level of wholesale electricity prices. The coefficients imply that after the closure of the first three coal plants the wholesale Dutch electricity price is 1.76 euros lower than before the closure, while it is 1.73 euros lower than before after the subsequent closure of the last two coal plants.

This result is contrary to the ACM's forecast that an increase in price would occur following the Closure Agreement. However, the OLS results are not reliable since they suffer from several time-series related econometrics issues that we need to control for and check whether the results are robust.

3.3 Robustness analysis

Given the time-series nature of the data collected, we apply statistical tests on the presence of ARCH effects (e.g. persistence in the volatility of the error term), autocorrelation in the dependent variables and non-stationarity.

We perform the Engle's Lagrange multiplier test to check for the presence of autoregressive conditional heteroskedasticity and the Breusch-Godfrey test to control for the presence of autocorrelation (Engle (1982); Breusch (1978)). The results suggest both the presence of ARCH effects and autocorrelation. We then apply the Augmented Dickey Fuller test on the presence of a unit root (Dickey and Fuller (1981). The result suggests that the commodities' and EUA's price series are non-stationary. These results are further confirmed when applying the KPSS test under which the null-hypothesis is stationarity (Kwiatkowski et al. (1992)). To address this issue, we detrend the time series (Enders

(1948)).[8] To solve for the above-mentioned issues, we perform a generalised ARCH model (GARCH) - allowing for both autoregressive and moving average components in the heteroskedastic variance. In the GARCH model, we include two lags of the dependent variable (AR) to address the autocorrelation issue and we include the commodities' and EUA's price series in a detrended form to address the non-stationarity issue (Enders (1948)).

Table A6 in Appendix A displays the results of the GARCH model with and without including the AR variables. All the supply and demand shifters still enter with the right sign and are significant. With respect to the dummies capturing the effect of Closure Agreement, the coefficients are still negative and significant. This suggests that the results are robust. Although we observe that the magnitude of all coefficients slightly decreases, this is consistent with the coefficients capturing the effect of GARCH components under the OLS method.

We observe that when the two AR variables are included, the magnitude and the significance of all coefficients decreases significantly. This is in line with expectations. In fact, even though the dependent variable does not have a unit root, it is likely quite persistent. This, in turn, implies that including two lags of the electricity price is taking out most of the variation, worsening the estimation results. An alternative way to control for autocorrelation, without eliminating most of the variation in the dependent variable, is to use Newey-West standard errors (Newey and West (1994)). As a sensitivity analysis, we have also performed the regression using Newey-West standard errors. When applying this method the results appear in line with the OLS results. We display the results in table A7 of Appendix A.

3.4 Discussion of findings

Both the OLS estimations and the Generalised ARCH estimation indicate a negative impact on prices following the closures of the coal-fired power plants, which is contrary to the ACM's ex-ante expectation of a positive price impact. However, these results are robust to several econometric robustness checks as discussed above.

[8] Refer to Appendix A tables A3, A4 and A5 for the results of the test

A possible explanation behind this negative price effect is that the closures of old coal-fired power plants leads to the usage of more efficient thermal plants which, in turn, have a depressing effect on price. In this respect, the dummies might be capturing not only the direct effect of the Closure Agreement, but also its indirect effect of increasing the level of efficiencies of pre-existing thermal plants, as well as the creation of new more efficient thermal plants. One method to control for the number of thermal plants would be to include the available installed-capacity. However, the latter is clearly correlated with the price of electricity and would create an endogeneity issue, which would lead to biased and inconsistent estimates. We acknowledge the possibility of using instrumental variables. However, the latter approach was not feasible due to the unavailability of accessible data at the power-plant level.

An alternative explanation could lie in the high level of interconnection between the Netherlands, Belgium and Germany. Given that we are only controlling for the level of imported German renewables, it could be that the coefficient of the dummies capturing the effect of the Closure Agreement might be affected by the high level of interconnection (e.g. imports and exports) with these countries. However, fully controlling for the level of interconnection was not possible due to the unavailability of data which covered the entire window of time analysed. Nevertheless, the level of interconnection is expected to be rather constant over time and should, therefore, not significantly affect the coefficient of the dummies.

Overall, despite the robustness of our results to the several sensitivities conducted, we acknowledge the limitations attached to a before-and-after analysis. Although it provides preliminary evidence of the effect of Closure Agreement, it does not consider any control group. We, therefore, do not know what would have happened absent the Closure Agreement . It could be that the same negative effect on prices would have occurred. A possible solution to this would be to perform a difference-in-difference analysis. However, such an analysis could not be performed due to data availability limitations.

In conclusion, we have not found the positive price effect anticipated by the ACM in its ex-ante assessment.

4 Critique of the ACM's emission evaluation

In the following section, we critique the ACM's evaluation of the estimated reduced emissions. For the purpose of our analysis, we use the baseline scenario provided by the ACM report. The ACM expected that the Closure Agreement would result in an annual reduction of 1.5 kton of NO_x, 2.0 kton of SO_2, 0.1 kton of particles (referred to as PM_{10}) and 4,700 kton of CO_2. Furthermore, the ACM expected that Closure Agreement would result in an annual cost of €75m due to an increase in the wholesale price of electricity, resulting from a reduction in installed electricity generation capacity (c. 10%).

We demonstrate that if the reduction in emissions was evaluated using the methodology used by the Dutch Government in mid-2018 (a year after all the coal plants closed), the outcome of the ACM's cost benefit analysis would be different. First, we examine how the valuation of reduced NO_x, SO_2 and PM_{10} emissions (non-CO_2 emissions) would have changed. Second, we consider why the ACM did not consider the reduction of CO_2 provided any benefit and how the decision would have been different in 2018. Third, we consider if an alternative evaluation method, using a Stated Preferences analysis of the willingness-to-pay (WTP) for Green Electricity products, could have been a more desirable approach to quantify the benefit of the Closure Agreement.

In Appendix B more details are provided on the calculations for the 2013 ACM valuation, as well as the updated mid-2018 valuations, while details on the WTP calculation are provided in Appendix C.

4.1 Explanation of the ACM trade-off evaluation in 2013

The ACM calculated the values for each tonne of reduced emission using the 2010 Shadow Prices Handbook (the 2010 Handbook), produced by the environmental consultancy CE Delft, which was commissioned by the Dutch Government (CE-Delft (2010)). The shadow prices (valuations of the benefit from reducing one tonne of an emission) of each emission in the 2010 Handbook are specific to the Netherlands and are calculated using two different methods: Damage Costs and Abatement Costs.

Damage Costs are valuations based on the estimated damage occurring as a result of emissions and other changes in natural capital and are calculated based on people's willingness to pay not to damage the environment (CE-Delft (2010)). On the other hand, Abatement Costs are based on the costs required to secure binding environmental policy targets. They are calculated as the cost of the most expensive technique required to meet government emission targets. The logic for using the Abatement Cost method is that, when a binding national target exists, efforts to reduce emissions will not result in reductions of overall emissions (as the Government will inevitably find a way to meet the target). Instead, the question is whether the environmental intervention that is being evaluated is cost efficient compared to other reduction methods that are being used (CE-Delft (2010)).

On the one hand, Damage Costs shadow prices benefit from being estimates of the true costs of emissions. Its shortcoming is that it can be complicated to construct and valuation can be inaccurate if based on old studies (Tol (2002)). On the other hand, Abatement Costs benefit from being simpler to calculate (requiring less assumptions and information) than Damage Costs and producing valuations that facilitate cost efficient policy decisions. Its shortcoming is that discerning the marginal cost of abatement involves ranking the costs of different government policies required to meet current emissions targets, and such a ranking of abatement methods can be prone to error (Ward (2014)).

In 2013, Abatement Costs were the preferred valuation method whenever the Dutch Government had set a national reduction target (CE-Delft (2018)). The ACM therefore relied on the Abatement Cost valuations in the 2010 Handbook for NO_x and SO_2. However, Damage Costs were used for PM_{10} emissions, as there was no national reduction target for PM_{10} at the time. The ACM disregarded the estimated annual reduction in CO_2 emissions, due to the Waterbed Effect. Using the 2010 Handbook shadow prices, the ACM determined that the Closure Agreement would result in an annual benefit of €30m, lower than the estimated annual cost (€75m). Given that there would be an annual net cost of €45m, the ACM concluded that the Closure Agreement would be anti-competitive (see Table B.1 in Appendix B for the details).

4.2 Re-evaluation of the benefits of non-GHG emissions

If the evaluation had been done by the Dutch Government in mid-2018, there would have been two major methodical changes compared to the ACM's approach in 2013. The first methodological change was that the Dutch Government abandoned its previous recommendation that Abatement Costs should be used for the valuation of emissions for which targets had already been set. Less than a year after the 2013 ACM decision, the new General Social Cost Benefit Analysis Guidelines outlined that emission valuations should be valued using Damage Costs, and other methods should only be used if this is not possible (CPB and PBL (2013)). The only exception to the preference for Damage Costs are evaluations related to climate change (e.g. CO_2 and other GHGs), for which the Dutch Government's Discount Rate Working Group recommended using the Abatement Cost method (Ministerie van Financien (2015)). The shift from the Abatement Cost to Damage Cost methodology increased the valuation of the reductions of NO_x and SO_2 emissions. The second methodological change was that CE Delft updated the Damage Cost valuations of its previous 2010 Handbook with the new *Environmental Prices Handbook 2017* (the 2017 Handbook). In this, it presented a range for all shadow prices; these were Lower, Central and Upper valuations for reduced emissions, which reflected varying assumptions (CE-Delft (2018)).

These methodological changes lead to an increase to the valuation of certain reduced non-CO_2 emissions. In particular, while NO_x emissions were previously valued at 9.4 €/kilo using the Abatement Costs method, they would be valued at 11.4 €/kilo using the Damage Cost shadow prices in the 2010 Handbook. This valuation increases further to a 34.7 €/kilo Central valuation (or alternatively a 24.1 €/kilo Low valuation and a 53.7 €/kilo Upper valuation) when using the Damage Costs valuations from the 2017 Handbook (see Table B.3). Using the 2017 Handbook's Damage Costs, the benefit from all the reduced Non-CO_2 emissions ranges from €75m to €165m per year, with a Central Valuation of €135 million per year. Therefore, if the ACM would have assessed the value of the estimated non-CO_2 emissions reductions in mid-2018, it would have estimated a net benefit of €60 million per year (using the Central valuation). Crucially, this implies that the ACM would not have found the Closure Agreement to be anti-competitive once all the coal plants closed, even if it only considered the reduction in Non-CO_2 emissions.

4.3 Re-evaluation of the benefits of the CO_2 emissions

The ACM did not consider there to be any benefit from the annual 4,700 kton reduction in CO_2. This was because although there would have been an annual reduction of CO_2 in the Netherlands, the ACM argued that due to the EU ETS, the Closure Agreement would simply free up CO_2 allowances and lead to emissions being shifted to elsewhere in the EU (ACM (2013)). This shifting of CO_2 emissions to elsewhere following CO_2 reduction efforts is known as the 'Waterbed Effect'. The ACM noted that although there would be a resulting benefit in the form of a marginal reduction in the cost of CO_2 emissions across the EU, as Dutch consumers would only reap a small share of the benefit of this EU-wide reduction, it should not be counted. This approach was consistent with the position of the Dutch Government's Bureau for Economic Policy Analysis (CPB (2013b)) (CPB (2013a)). However, had the evaluation been done in mid-2018, a cost-benefit analysis of the Closure Agreement would have included CO_2 emission reductions, given changes in Dutch government policy in 2016 and reforms to the EU ETS' Market Stability Reserve (MSR) in 2018.

The Dutch Government publicly disregarded the Waterbed Effect and changed its approach in later years. In a 2016 report, the Government argued that the manner in which the Dutch Government now considers future climate scenarios means that the "waterbed effect does not need to be taken into account" (CPB and PBL (2016)). The 2016 report notes that while the previous approach focused on measuring the benefit from moving to a new scenario where there was less CO_2 (due to a policy intervention), the new approach instead focuses on whether the cost at which a reduction occurs is efficient given the applicable CO_2 reduction target. The new approach also relies on a range of valuations, which reflect the uncertainty surrounding international climate policy and what the CO_2 reduction target could be in the future. There are three valuations, called "Low", "High" and "2°C" (reflecting that the reductions required to avert a 2°C rise by 2050 compared to 1990 levels will actually be met). These scenarios are reflected in the CO_2 Abatement Cost shadow prices in CE Delft's updated 2017 Handbook.

Furthermore, in February 2018 changes were made to the EU ETS MSR allowing for the removal and the cancellation of past excess allowances, which mitigates the Waterbed Effect. Perino (2018) notes that this effect is retroactive, as the number of allowances that are ultimately cancelled depends on the number of unused allowances in the market at the end of 2017 and thereafter. This means that even if allowances were freed up before the 2018 reforms due to the Closure Agreement, it would still result in more allowances being removed from the market, thereby reducing the overall cap of CO_2 emissions in the EU. Perino (2018) explains that the mitigation of the Waterbed Effect is temporary, as allowances will continue to be removed from the market up until a certain threshold is reached. However, Rooijers et al. (2019) remark in the 2019 CE Delft Report that changes to the MSR will mean that an early closure of Dutch coal-fired units before January 1, 2022 will not have a 'waterbed effect' (CE-Delft (2019)). Therefore, it is expected that for the duration of the Closure Agreement (2016 to 2021), the Waterbed Effect is mitigated.

Given these considerations, it is clear that the ACM would have included the benefit from reduced CO_2 emissions, had the evaluation been done in mid-2018. Using the 2017 Handbook's Abatement Costs for CO_2, the Central valuation estimates of the benefit from the annual reduction of CO_2 emissions would be €270 million per year. This increases to €400 million per year once non-CO_2 emissions (NO_x, SO_2 and PM_{10}) are also included. Overall, the ACM would have found a net benefit ranging from €65m to €360m per year, with a Central valuation estimate of €325m (see Table B4 in Appendix B).

4.4 Alternative methodology: Stated Preferences Analysis

One year after the coal plants closed, the ACM's Central estimate of the annual benefits from the Closure Agreement would have been over €400m per year (using either the Central or Upper valuations from the 2017 Handbook). However, in 2013, the annual benefit was calculated as only €30 million. This proves that there is volatility in the valuation method used by Dutch regulators and government departments. This volatility is due to: (i) the Government switching from Abatement Cost to Damage Cost methods for non-CO_2 emissions, (ii) updates to Damage Cost valuations in the 2017 Handbook and (iii) changes to Dutch Government policy on the inclusion of CO_2 reduction in cost benefit analysis. Given this volatility, we consider if the ACM could have used an alternative methodology for evaluating the benefits of the Closure Agreement in 2013, which would not have been directly affected by shifts in Dutch Government environmental policy.

We therefore seek to estimate Dutch consumers' willingness-to-pay (WTP) for Green Electricity products and use this valuation as a proxy for consumers' valuation of reduced emissions as a result of the Closure Agreement. We employ a Stated Preferences analysis, using data from a survey that was commissioned by the ACM in 2013, which we will refer to as the 2013 Survey (Marketresponse (2013)). The 2013 Survey asked a sample of Dutch consumers whether they would pay extra for Green Electricity products (c.25%) and, if so, how much more per month would they be willing to pay (c.€12). We interpreted Dutch consumers' WTP for Green Electricity as being equivalent to their WTP for electricity that is from 100% renewable sources, which therefore produces zero CO_2 emissions. To estimate the WTP for the Closure Agreement, we combined the survey results with our knowledge on the number of Dutch households (c.8m), annual CO_2 emissions created from Dutch electricity (c.55 Mt) and the ACM's estimate of the annual reduction in CO_2 (4.7 Mt).

This approach has several strengths compared to the approach the ACM used in 2013. In addition to being fast and simple, this approach benefits from not being directly affected by future shifts in Dutch Government policies on emission evaluations, as well as changes to Damage Cost valuations. We expect that unlike the ACM's assessment (which would have increased from €30m in 2013 to over €400m in 2018), valuations based on consumer WTP should be more stable from year to year.

Using this method, we calculated Dutch consumers' aggregate WTP for the annual reduction in emissions (due to the Closure Agreement) to be €24.6m (the calculations' details are set out in Appendix C). Compared to all measures discussed so far, this is the lowest. The result therefore indicates this approach leads to an undervaluation of the reduced emissions, which is a major weakness. This low valuation is consistent with the economic theory with regards to the private provision of a discrete public good. As noted by Varian (1992), by definition, public goods are non-excludable. As a result, consumers can prefer to free-ride on other consumers, as opposed to making private voluntary contributions that are aligned to the efficient provision amount. Paying a premium for Green products (such as Green Electricity), is effectively a private contribution to a public good (abating pollution and climate change) and as a result consumers' aggregate WTP is unlikely to equal the social benefit derived from the public good. Given our result and the economic theory surrounding public goods, we suspect that any attempt by regulators to use consumer

WTP for Green Products in any country (where consumers pay a premium for improving, or reducing harm to, the environment) will likely result in similar undervaluations. We therefore consider that using estimations of the WTP for Green products (using Stated Preference analysis, or otherwise) will be an unsuitable method for ex-ante assessments of reduced emissions.

5 Conclusion

In hindsight, our findings suggest the ACM was likely incorrect to oppose the Closure Agreement. The early closures did not appear to result in the anticipated increase in the wholesale price of electricity, implying that the Closure Agreement had no cost. Furthermore, given subsequent changes to the methods for valuing reduced emissions used by the Dutch Government, the benefit of the Closure Agreement would be regarded as far higher if evaluated today.

We have two suggestions for regulators and policy makers who undertake ex-ante assessment of future Green Agreements relating to the early closure of coal or gas power plants. First, given the before-and-after analysis did not find evidence of a significant price increase, it should not be taken for granted that plant closure agreements will always result in a cost. Second, given that we have proven that Damage and Abatement Cost methodologies can be volatile (and that using WTP for Green products is an unviable alternative), we suggest that those undertaking future ex-ante assessments of plant closure agreements should present the benefits of reduced emissions as a range reflecting the spectrum of possible changes in environmental policy. This would require regulators to coordinate better across government departments, in order to understand which methodologies are currently subject to scrutiny and could possibly change in the future. Regulators in EU Member States should also work more closely with EU institutions, in order to anticipate possible changes to European environmental policy (such as the yet enacted policy initiatives under the Green New Deal), which could have future implications for the valuations of reduced emissions that are used today.

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Appendices

A Relevant outputs from the econometrics analysis

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Table A1: Descriptive statistics of the main variables included in the model

	Electricity Price	Gas Price	EUA Price	Oil Price	Coal Price	Air Temp.	Wind Speed	Hours of Sun
mean	43.28	56.61	11.80	61.48	63.97	10.75	4.40	5.07
max	98.98	88.98	33.29	96.67	100.87	28.93	13.01	15.48
min	-5.45	9.27	2.70	17.84	35.17	-10.95	1.02	0.00
sd	10.77	16.68	7.49	17.27	14.56	6.15	1.83	3.88
variance	115.96	278.28	56.11	298.29	212.09	37.86	3.35	15.08
N	4018							

Table A2: Yearly mean value of the main variables included in the model

	Electricity Price	Gas Price	EUA Price	Oil Price	Coal Price	Air Temp.	Wind Speed	Hours of Sun
2010	45.41	48.22	14.39	60.46	69.55	9.04	4.11	4.81
2011	52.01	67.21	13.08	79.28	87.47	10.86	4.53	5.01
2012	48.03	72.97	7.39	86.40	72.30	10.22	4.39	4.69
2013	51.93	78.99	4.49	81.89	61.58	9.74	4.46	4.66
2014	41.20	63.35	5.97	74.58	56.69	11.65	4.33	5.00
2015	40.02	58.48	7.68	48.38	51.08	10.86	4.69	5.14
2016	32.29	42.89	5.37	40.80	53.90	10.73	4.23	5.13
2017	39.27	51.71	5.84	48.61	74.57	10.95	4.33	4.79
2018	52.59	66.95	15.95	60.67	77.98	11.35	4.28	5.70
2019	41.15	43.31	24.87	57.36	54.85	11.22	4.39	5.33
2020	32.28	28.75	24.74	37.91	43.80	11.65	4.68	5.47
10-y avg.	43.28	56.61	11.80	61.48	63.97	10.75	4.40	5.07

Table A3: Augmented Dickey-Fuller Test Results

	Interpolated Dickey-Fuller				MacKinnon
	T-Stat	1% Critical Value	5% Critical Value	10% Critical Value	P-Value
Coal	-2.067	-3.960	-3.410	-3.120	0.5644
Gas	-2.750	-3.960	-3.410	-3.120	0.2159
Oil	-3.868	-3.960	-3.410	-3.120	0.0134
EUA	-1.018	-3.960	-3.410	-3.120	0.9416

The ADF test includes two lags. Results do not change by including more lags.

Table A4: LM test results for autoregressive conditional heteroskedasticity (ARCH)

Lags	χ^2	df	Prob $>\chi^2$
1	530.089	1	0.0000
2	541.913	2	0.0000

Table A5: Breusch-Godfrey LM test results for autocorrelation

Lags	χ^2	df	Prob $>\chi^2$
1	1179.049	1	0.0000
2	1200.030	2	0.0000

Table A6: Generalised ARCH model results

	(1)	(2)
Wholesale Electricity Price		
Closure 1	-1.429***	-0.780*
	(-3.58)	(-2.12)
Closure 2	-1.569***	-0.611
	(-4.58)	(-1.95)
Gas	0.388***	0.152***
	(28.15)	(10.84)
Oil	0.0462***	0.0230*
	(4.26)	(2.43)
Coal	0.128***	0.0487***
	(8.62)	(3.66)
EUA	0.896***	0.376***
	(22.26)	(9.51)
Temperature	-0.188***	-0.132***
	(-9.29)	(-6.81)
Wind Speed	-0.703***	-0.0145
	(-5.14)	(-0.11)
WInd Speed Squared	0.0125	-0.00396
	(1.02)	(-0.36)
Wind Speed Germany	-0.00721	-0.00170
	(-0.88)	(-0.20)
Hours of sun	-0.00111	0.0513**
	(-0.06)	(2.75)
AR 1		0.545***
		(27.00)
AR 2		0.0609***
		(3.44)
Constant	-10.04***	-8.450***
	(-9.24)	(-8.40)
ARCH		
Arch 1	0.493***	0.206***
	(16.50)	(11.10)
Arch 2	-0.359***	-0.115***
	(-11.05)	(-6.45)
Garch 1	0.826***	0.853***
	(37.77)	(54.51)
Constant	1.215***	0.997***
	(6.33)	(6.79)
N	4018	4016

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The day of the week, month and year fixed effect are all included in the estimation.
They are not displayed for space purposes

Table A7: Regression results with Newey-West standard errors

	(1)
Closure 1	-1.774**
	(-2.79)
Closure 2	-1.792***
	(-3.46)
Gas - detrended	0.425***
	(18.81)
Oil - detrended	0.0386*
	(2.07)
Coal - detrended	0.0766**
	(2.88)
EUA - detrended	0.981***
	(14.65)
Temperature	-0.410***
	(-7.32)
Wind Speed	-1.271***
	(-5.86)
Wind Speed Squared	0.0527*
	(2.50)
Wind Speed Germany	-0.00828
	(-1.25)
Hours of Sun	0.0183
	(0.58)
Constant	35.77***
	(34.56)
N	4018

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The day of the week, month and year fixed effect are all included in the estimation. They are not displayed for space purposes

Table A8: Data sources

Daily Electricity Price	Bloomberg	daily
Price of EUA for CO2[1]	https://ember-climate.org	daily
Price of Gas[1]	investing.com	daily
Price of Oil	investing.com	daily
Price of Coal	investing.com	daily
Temperature	KNMI - Dutch metereological institute	hourly (considered daily average)
Wind Speed	KNMI - Dutch metereological institute	hourly (considered daily average)
Wind Speed in Germany	DWD - German meterological institute	hourly (considered daily average)
Hours of Sun	KNMI - Dutch metereological institute	hourly (considered daily average)

[1] Price of Futures. The price of Futures closely follows the underling spot price that generates it.

B Emission Evaluation Calculations

In this appendix we provide more detail on how the ACM estimated the benefit from the estimated reduction in emissions, as well as how the evaluation would have changed if it had been done in mid-2018 (one year after the coal plants closed).

B.1 The ACM trade-off evaluation in 2013

In the ACM's assessment of the Closure Agreement (ACM (2013)), it noted that the Closure Agreement would result in an annual reduction of 1.5 kton of NO_x, 2.0 kton of SO_2, 0.1 kton of particles (referred to as PM_{10}) and 4,700 kton of CO_2. It determined that the reductions of NO_x, SO_2 and PM_{10} emissions should be valued at EUR €9.40, €5.40 and €44.30 per kilo respectively. The reduction in CO_2 emissions was not considered to have any benefit. As a result of these valuations, the Closure Agreement was estimated to have an annual benefit of approximately €30m. Given that the ACM estimated an annual cost of €75m (due to the expected increase in the wholesale price of electricity) as a result of the Closure Agreement, it anticipated that there would be a net cost of approximately €45m per year.

Table B.1: ACM 2013 evaluation

	NOx	SO2	PM10	CO2	Annual Benefit	Net Cost
Yearly Ktons emissions reduction	1.5	2	0.10	4,700		
2013 ACM evaluation	9.4	5.4	44.3	0.0	29.33	**-45.67**

B.2 Methodology used for the ACM trade-off evaluation in 2013

As explained in Section 4, the ACM calculated the values for each tonne of reduced emission using the 2010 Handbook (produced by the environmental consultancy CE Delft), which was commissioned by the Dutch Government (CE Delft, 2010). The 2010 Handbook sets out shadow prices (prices that reflect the benefit of reducing one tonne of an emission) for different emission types, using both the Abatement Cost method and the Damage Cost method. These valuations (for both the Abatement Costs and Damage Costs methods) were calculated to specifically measure the benefit from reducing emissions in the Netherlands in the year 2008. When evaluating the benefit of reducing emissions in the Netherlands after the year 2008, the valuations are meant to be adjusted for inflation.

In line with the Dutch Government's approach to valuing reduced emissions, the ACM sought to use Abatement Cost valuations whenever possible. Abatement Costs were therefore used for the valuation of NO_x and SO_2 emissions, while Damage Costs were used to value PM_{10} emissions (as no clear national reduction target for PM_{10} emissions at the time). The 2010 Handbook outlines that NO_x and SO_2 emissions are valued at EUR €8.72, €5.00 and €41.00 per kilo respectively. The ACM applied an uplift of 8% to these valuations, which seems to reflect inflation. The 8% increase approximately reflects the Dutch CPI increase from 2008 to 2012, although the ACM precise inflation adjustment method (and the index it used) is not clear from its 2013 decision memo (ACM (2013)).

Table B.2: 2010 CE Delft evaluation using 2008 prices vs. ACM 2013 evaluation

	NOx	SO2	PM10	CO2	Annual Benefit (€m)	Net Benefit (€m)
Yearly Ktons emissions reduction	1.5	2.00	0.10	4,700		
2013 ACM evaluation	9.4	5.4	44.3	0.0	29.33	**-45.67**
2010 CE Delft evaluation[1]	8.72	5.00	41.00	0.0	27.18	**-47.82**

[1] 2008 *prices*

B.3 Re-evaluation of the benefits of non-GHG emission

In 2018, CE Delft revised its emission shadow prices and published its (confusingly titled) 'Environmental Prices Handbook 2017' (2017 Handbook), where its valuations of reduced emissions were tailored specifically to emissions that occurred in the Netherlands in the year 2015 (CE-Delft (2018)).

As explained in Section 4, by 2018 the Dutch Government had abandoned its previous recommendation that Abatement Costs should be used for the valuation of emissions for which targets had already been set. Instead it advised that Damage Costs valuations should be used for all emissions, besides GHG emissions. The 2017 Handbook therefore only had Damage Cost valuations for NO_x, SO_2 and PM_{10} emissions, which are listed in the table below. It should be noted that the table below does not reflect the benefit from the reduction in GHGs (i.e. CO_2)

The Damage Cost valuations in the 2017 Handbook were significantly more than that

Table B.3: CE Delft 2017 Handbook Evaluation (excl. CO2)

	NOx	SO2	PM10	CO2	Annual Benefit (€m)	Net Benefit (€m)
Yearly Ktons emissions reduction	1.50	2.00	0.10	4,700		
2013 ACM evaluation	9.4	5.40	44.30	0.0	29.33	**-45.67**
2017 Handbook, excl. CO2 (low)[1]	24.1	17.7	31.8	-	74.73	**-0.27**
2017 Handbook, excl. CO2 (central)[2]	34.7	38.7	44.6	-	133.91	**58.91**
2017 Handbook, excl. CO2 (upper)[2]	53.7	38.7	69.1	-	164.86	**89.86**

[1,2,3] *Source : CE Delft*, 2017.

2010 Handbook for certain emissions. For example, while the Damage Cost shadow price for NO_x emissions was €11.38 in the 2010 Handbook, even the 2017 Handbook's Low Damage Cost shadow price for NO_x was more than double that (€24.1).

It should be noted that we have not adjusted the valuations in the 2017 Handbook for inflation. In order to reflect that the ECN calculated the annual emission reductions as being in net present value terms for 2013, the shadow prices should be slightly less than the 2015 valuations in the 2017 Handbook. However, given the magnitude of the increase in the shadow prices using the 2017 Handbook (compared to the ACM's evaluation in 2013), taking into account inflation would not have a material effect on our overall results.

B.4 Re-evaluation of the benefits of the CO_2 emissions reduction

In 2016, the Dutch Government changed its approach to its evaluating the reduction of CO_2 emissions that are subject to the EU ETS. In a 2016 report, the Government set out three possible different valuations, called "Low", "High" and "2°C" (reflecting that the reductions required to avert a 2°C rise by 2050 will actually be met) (CPB and PBL (2016)). These scenarios are reflected in the CO_2 Abatement Cost shadow prices in CE Delft's updated 2017 Handbook, although the shadow prices in the 2016 report have been increased in order to reflect VAT in the Netherlands.

In the table below, we set out low, central and high valuations for the emission reductions. This includes the benefit from the non-GHG emissions from Table B.3, in addition to benefit from CO_2 reductions. The low, central and upper valuations reflect the respective inclusion of the Low, High and 2°C valuations for CO_2 in the 2017 Handbook. It is worth noting that the High and 2°C valuations for reducing one tonne of CO_2 are effectively the same.

Table B.4: CE Delft 2017 Handbook Evaluation (inc. CO2)

	NOx	SO2	PM10	CO2	Annual Benefit (€m)	Net Benefit (€m)
Yearly Ktons emissions reduction	1.50	2.00	0.10	4,700		
2013 ACM evaluation	9.4	5.4	44.3	0.0	29.33	**-45.67**
2017 Handbook, inc. CO2 (low)[1]	24.1	17.7	31.8	0.014	140.53	**65.53**
2017 Handbook, inc. CO2 (central)[2]	34.7	38.7	44.6	0.057	401.81	**326.81**
2017 Handbook, inc. CO2 (upper)[3]	53.7	38.7	69.1	0.057	432.76	**357.76**

[1,2,3] *Source : CE Delft*, 2017.

C Stated Preferences Analysis

In this appendix, we set out the calculations and assumptions that were used for the Stated Preferences analysis of the Willingness to Pay for Green Electricity, as set out in Section 4. This is a simple back-of-the-envelope calculation aimed at providing a general idea of whether using the WTP for a Green Product is a viable methodology. We therefore use several assumptions, as well as rounded numbers, in order to keep the calculation simple.

C.1 Data source

A key advantage of this method is that it can rely on information that would have been available to the ACM at the time of its assessment. The source is data from a survey produced by the Dutch consultancy Marketresponse, which was commissioned by the ACM in 2013 (Marketresponse (2013)). We will refer to this as the 2013 Survey. There was an additional follow-up report published by Marketresponse in 2014, covering the results of two surveys carried out in 2013, which we will refer to as the 2014 Survey (Marketresponse (2014)). The table and figure below incorporates information from both the 2013 Survey and the 2014 Survey.

The tables and figures below illustrate that consumers' responses appear to be relatively stable between 2010 and 2013. In particular, the proportion of respondents that are willing to pay extra for Green Electricity is approximately 25%, while the extra amount that such consumers are willing to pay is approximately €12 per month. These are still reasonable approximations when looking at only the 2013 Survey results (2010 to 2012), which are the only results that the ACM would have had access to at the time of their evaluation.

Table C.1: Wiillingness to pay extra for green electricity

Willingness to pay extra	2011-1	2011-2	2012-1	2012-2	2013-1	2013-2
1-4	2	5	6	5	4	9
5-9	20	11	18	26	23	15
10-14	29	31	31	16	19	27
15-19	7	4	4	3	8	7
20-24	6	7	6	4	7	9
25 or more	8	6	6	9	8	5
Do not know	0	0	28	0	31	28
Average	€ 12.57	€ 11.51	€ 12.26	€ 11.36	€ 11.94	€ 12.05

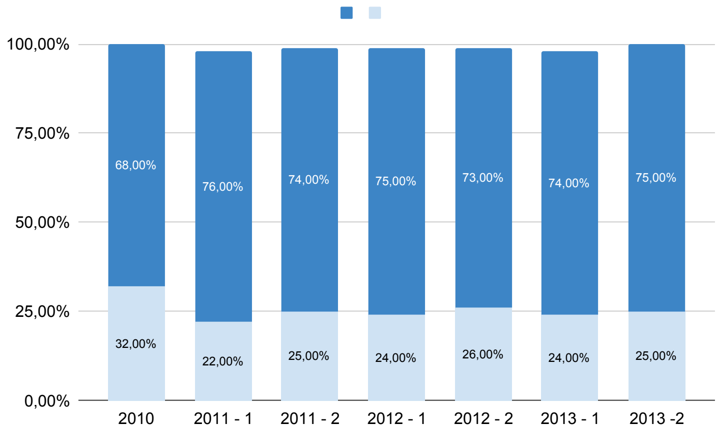

Figure C.1: Percentage of people willing to pay extra for green electricity

C.2 Construction of the Stated Preferences methodology

We have to rely on various assumptions in order to first determine the aggregate WTP for the green electricity premium, and then use this aggregate willingness to pay to value the benefit from the environmental intervention (i.e. the Closure Agreement).

C.2.1 What does the WTP for Green Electricity actually reflect?

The 2013 Survey asked consumers if they would pay extra for "Green Electricity", however it did not provide an any definition of Green Electricity or provide any information on the impact that Green Electricity has on the environment. The 2013 Survey simply seems to refer to general Green Electricity tariffs bought buy retail consumers. Therefore, for the purpose of this Stated Preferences analysis, we interpret the answer to this survey as customers' WTP for retail Green Electricity, which in turn reflects a WTP for electricity that is from 100% renewable sources. This would therefore be consumers' WTP for a scenario where zero emissions would be created from electricity produced in the Netherlands.

C.2.2 Aggregate annual value of green electricity

If 25% of people would be willing to pay an average of €12 extra per month for green electricity, we can average this out as a valuation by the average retail customer of €3 (12*0.25) extra per month, or €36 extra per year. The number of Dutch residential households in 2013 was approximately 8 million (7.569m according to Statistics Netherlands

(CBS) website (CBS (2020))). As each Dutch consumer is willing to pay approximately €36 per year for electricity with zero emissions, the aggregate valuation of Green Electricity across all households in the Netherlands is €288m.

C.2.3 Application to reduced the Closure Agreement

The coal plants closure will make electricity greener, but not reduced emissions to zero. In 2013, the ACM anticipated the closure would produce 4.7 less megatons of CO_2 each year. This would therefore be 8.55% less CO_2, compared to c.55 megatons in 2013 produced by Electricity and Heat Producers in the Netherlands (IEA (2020)).[9] This is of course different from electricity with zero emissions, which we assume is represented in the WTP for Green Electricity products. However, if we assume that consumers' WTP for electricity increases in proportion to the reduction in CO_2 compared to fully Green Electricity (which is entirely from renewable sources), then we could say that consumers would be willing to pay 8.55% of the amount they would pay for Green Electricity.

C.3 Final Calculation

In summary, the aggregate valuation of Green Electricity across all households in the Netherlands is €288m per year (12*0.25*12*8,000,000) and the Closure Agreement should provide 8.55% of the benefit of Green Electricity. This gives an overall benefit of €24.6m (0.0855*12*0.25*12*8,000,000).

[9]These Dutch emission levels from 2013 were obtained from the the International Energy Agency's website. The information is also set on in 'Figure 3.2' of their 2020 reports entitled 'The Netherlands 2020: Energy Policy Review' (IEA (2020))