

The economics of Greek lignite plants: End of an era.



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Executive Summary

The double failure to sell lignite assets in Greece and the rapid deterioration of the financial status of the Public Power Corporation (PPC) has spurred the public debate around the retirement of lignite plants. Understanding the profitability of the Greek lignite industry is critical in designing the necessary measures to transform PPC into a financially healthy company, while shifting Greece's energy model towards a sustainable direction. To this end, this report has three goals:

- 1. To shed light into the economics of Greek lignite plants in the last 3,5 years.
- 2. To provide an outlook for the Greek lignite industry in the next 3,5 years.
- 3. Based on that, to recommend specific actions to improve the current situation.

Key findings:

Using a simple model for the estimation of the monthly gross and net profits of each lignite unit in conjunction with publicly available data and realistic assumptions about the future values of key parameters influencing the profitability of Greek lignite plants, we find that:

- 1. During the 3,5 year period from January 2016 until June 2019, PPC has accumulated a net loss of $\notin 683$ million from the operation of its lignite units.
- 2. If the current lignite fleet remains as is, then in the next 3,5 years, the situation will deteriorate and the lignite industry will accumulate losses of the order of €1,3 billion.
- 3. No scenario out of the 4 constructed and analyzed can lead to a net profit of the Greek lignite industry in the next 3,5 years even for carbon prices significantly lower than the analysts' predictions; even if a hedging strategy is successfully implemented.

Key Policy Recommendations:

- 1. *The immediate retirement of the Kardia and Amyntaio plants is highly recommended* since it will vastly improve the economics of PPC by slashing the lignite-fleet's projected net losses by over €600 Million in the next 3,5 years.
- 2. Provided that 3 TWh of electricity per year can be produced by other sources of energy, *the additional retirement of the Ag. Dimitrios I-II and Megalopoli IV units is also recommended*, since it will bring down the annual net losses of Greece's lignite industry to less than €130 million, a 66% improvement compared to the scenario where no retirement takes place, and almost at the same levels of combined net losses in the previous 3,5 years.
- 3. Given the escalating carbon prices and the fact that Greek lignite plants have by far the highest carbon intensity in the EU, *Greece must commit to a specific retirement schedule of all lignite units until 2030 at the latest*. This report's recommendations



for lignite unit retirements may contribute towards identifying the units that need to retire first.

Figure A: Cumulative gross and net profits of all lignite plants for the period <u>January 2016-June</u> 2019



Figure B: Cumulative estimated gross profits, net profits and fixed costs for Greek lignite units for the period <u>July 2019-December 2022</u> under 4 scenarios. The first data point for the gross profit, net profit and fixed costs lines shows the corresponding results for the preceding 3,5 year period (January 2016-June 2019). The shaded bands around the gross profit and net profit lines correspond to calculations with carbon prices 20% below (upper bound) and 20% above (lower bound) the nominal value.

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Introduction

On July 15, 2019, the second attempt to sell part of the lignite assets owned by the Public Power Corporation (PPC), failed¹, following the fate of the first attempt on February 6². The lignite sale was agreed between the then Greek government and the European Commission and was embedded in the Supplemental Memorandum of Understanding in 2017³. The underlying rationale behind this decision was that the engagement of other companies in the exploitation of Greek lignite would increase the competitiveness of the electricity market, which would, in turn, lead to lower electricity prices for consumers. However, the lack of investor interest in the lignite assets up for sale proved beyond any reasonable doubt that this decision was flawed.

At the same time PPC finds itself in the worst financial state of its history. The most recent financial results of the biggest publicly owned company in Greece showed losses of €233,5 million in the first quarter of 2019 (excluding the results for the lignite assets up for sale), a €214,8 million deterioration compared to the same period last year. One of the major factors contributing to this outcome was the escalation of the carbon prices, as cited in PPC's relevant announcement⁴.

Despite these developments, both the previous government and the previous administration of PPC were dedicated towards prolonging the lignite-based electricity model in Greece. They continued the construction of the \in 1,4 billion "Ptolemaida V" lignite plant, while seeking derogations from the European environmental legislation to subsidize its operation. The Greek government did not even hesitate to unilaterally interpret the Industrial Emissions Directive in order to grant lifetime extensions to Thermal Power Stations (TPS) Amyntaio and Kardia, which account for 42% of Greece's current lignite capacity.

Given the change in the government following the July 7, 2019 national elections, as well as in the administration of PPC, a fresh look into these choices is timely and appropriate. To this end, this report has three goals:

- 1. To shed light into the economics of Greek lignite plants in recent years.
- 2. To provide an outlook for the Greek lignite industry in the near future.
- 3. Based on that, to recommend specific actions to improve the current situation.

In the following sections, we first outline the methodology, data and assumptions used in our analysis. We then present and discuss the results of the economic analysis for the last 3,5 years. We subsequently analyze 4 different scenarios for the evolution of lignite economics in the next 3,5 years based on realistic assumptions about key parameters. Finally, we make specific recommendations guided by the findings of this report.

¹ 2019, July 15. PPC announcement <u>https://bit.lv/2TubI7a</u>

² 2019, February 8. PPC announcement <u>https://bit.ly/2Z3NplU</u>

³ 2017, July 5. Supplemental Memorandum of Understanding (second addendum to the Memorandum of Understanding) between the European Commission acting on behalf of the European Stability Mechanism and the Hellenic Republic and the Bank of Greece https://bit.ly/2Z77vvF

Methodology and Assumptions

Our analysis is based on the estimation of the monthly gross and net profits for each of the 14 existing lignite units in Greece's lignite fleet (see Table 1). We used data from the Greek Energy Exchange Group, the Greek Power Transmission Operator, the electricity market operator, the ETS, the ministerial decisions setting a lower value for the NOME auctions⁵ and PPC's annual reports.

Plants	Stacks	Units	Net Capacity (MW)
	Ag Dimitrios I II	Ag. Dimitrios I	274
	Ag. Dilliti 105 I-II	Ag. Dimitrios II	274
Ag. Dimitrios	Ag Dimitries III IV	Ag. Dimitrios III	283
	Ag. Dilliti los III-IV	Ag. Dimitrios IV	283
	Ag. Dimitrios V	Ag. Dimitrios V	342
Amuntaio	Amuntaio I II	Amyntaio I	273
Alliyillaio	Alliyital01-11	Amyntaio II	273
	Kardia I	Kardia I	271
Kardia	Kardia II	Kardia II	271
	Kardia III	Kardia III	280
	Kardia IV	Kardia IV	280
Megalopoli III	Megalopoli III	Megalopoli III	255
Megalopoli IV	Megalopoli IV	Megalopoli IV	256
Meliti	Meliti I	Meliti I	289
Total			3.904

Table 1: Greek Lignite Plants, stacks, and units and their net capacities

The gross profit (GP) (profit before fixed costs) of a lignite unit is the difference between the revenue from electricity sales (ES) and the sum of the CO_2 costs (C_{CO2}) and the rest of variable costs (VC). It can then be expressed by the following equation:

$$GP = ES - C_{CO2} - VC \tag{1}$$

The net profit (NP) is computed by subtracting the fixed costs (FC) from the gross profit (GP):

$$NP = GP - FC \tag{2}$$

Using the appropriate data, and equations (1) and (2) we computed the gross and net profits of each of the 14 existing lignite units and for each month in the 3,5 year period from January 2016 to June 2019.

Revenue from electricity sales

⁵ These are auctions where electricity produced by PPC is sold to other companies in order to fulfill the agreement contained in the Supplemental Memorandum of Understanding to reduce PPC's share in the electricity market to levels below 50% by 2020. According to the new Minister of Environment and Energy, this measure resulted in \notin 600 million losses for PPC.

The monthly revenues for each lignite unit, as well as data on the electricity prices, were obtained from the Greek Energy Exchange Group⁶.

<u>Carbon costs</u>

The monthly carbon costs for each lignite unit can be obtained from the equation:

$$C_{CO2} = ci \times cp \times E \tag{3}$$

where ci is the carbon intensity of the lignite unit in th CO_2/MWh ; cp is the carbon price in ϵ/tn CO_2 ; E is the electricity produced by the lignite unit in MWh. The monthly electricity production of each unit was obtained by ADMIE, the Greek Power Transmission Operator⁷.

To estimate the carbon intensity for each unit, we first obtained the annual carbon emissions for each lignite plant in Greece from the European Commission's EU Emission Trading System website⁸ for each year in the 3-year period 2016-2018. By dividing with the annual electricity production of each plant, the corresponding average carbon intensity was estimated for each year. Table 2 shows the average carbon intensities for each plant for the period 2016-2018. The monthly carbon intensity of each unit was assumed to be the same as the one for the corresponding plant, for each of the three years. For the first semester of 2019, the carbon intensities were assumed to be equal to the average of the period 2016-2018. The average carbon price for each month in the 42-month period under consideration was obtained by the operator of the Greek Electricity Market, LAGIE⁹.

This calculation is an approximation and it excludes the profit (or loss) of all forward hedges. Since PPC buys CO_2 allowances in advance, the exact carbon costs can be computed, only if the amounts of emission allowances and the corresponding carbon prices are known.

Plant	2016	2017	2018	Average
Ag. Dimitrios	1,507	1,467	1,522	1,499
Amyntaio	1,527	1,524	1,716	1,589
Kardia	1,529	1,579	1,592	1,567
Megalopoli III	1,776	1,840	1,904	1,840
Megalopoli IV	2,001	2,083	2,280	2,121
Meliti	1,255	1,294	1,278	1,276
Average	1,599	1,631	1,715	1,577

Table 2: Estimated average carbon intensities of Greek lignite plants

<u>Variable costs</u>

The variable costs (excluding CO₂ costs) of each lignite unit can be computed using the equation:

⁶ Greek Energy Exchange Group. <u>http://www.enexgroup.gr/nc/en/home/</u>

⁷ ADMIE, Independent Power Transmission Operator. <u>http://www.admie.gr/nc/en/home/</u>

⁸ European Commission, EU-ETS. <u>https://ec.europa.eu/clima/policies/ets_en</u>

⁹ LAGIE, Operator of Electricity Market. <u>http://www.lagie.gr</u>

where vc is the unit variable cost in \notin /MWh and E is the electricity produced by the given lignite unit in MWh. The unit variable cost, averaged for all lignite units, was obtained from the joint ministerial decisions (JMD) of 2017¹⁰, 2018¹¹ and 2019¹² for the determination of the lower price for the NOME auctions. It consists of a component related to the mine operations (parttime payroll, parts and consumables, electricity costs, maintenance, outsourcing), a component related to the operation of the plants (overtime payroll, parts and consumables, electricity costs, maintenance, ash and lignite yards, earth works). It also includes the costs of purchasing lignite, the power plant starting costs and the lignite levy of 2 \notin /MWh. Table 3 presents the average unit variable cost for each year in the period 2016-2018 based on the data presented in these decisions, each corresponding to the previous year. For the first semester of 2019, the average value of the previous three years was assumed to be the unit variable cost.

Unit cost	variable	2016	2017	2018	Average
<i>vc</i> (€/M	Wh)	26,60	25,83	27,96	26,80

Table 3: Average unit variable cost of Greek lignite plants

The abovementioned calculation of monthly variable costs is based on the annual, lumped unit variable costs for all lignite units. This is also an approximation since each unit has its own variable costs which change within each year. PPC only knows exact expenses per unit.

<u>Fixed costs</u>

As opposed to the variable and CO_2 costs, the fixed costs of a lignite unit do not depend on the level of electricity production. They consist of two components, one for the operation and maintenance of the lignite unit and one for the mines.

As far as the fixed unit costs are concerned, in its effort to indicate the mistakes Alouminion S.A. made in estimating the lignite-based electricity production cost, PPC stated¹³ that the fixed costs for the operation and maintenance of a new lignite unit such as Ptolemaida V, is \notin 35.000/MW. PPC also underlined that this figure does not apply to the older units in PPC's lignite fleet which are much less automated and require more maintenance. To account for this, we conservatively assumed that the average unit fixed costs of PPC's aging lignite fleet (consisting of units between 16 and 44 years old) were \notin 50.000/MW. Note that this estimate is 16,7% smaller than the fixed unit costs of German old lignite units, which according to the report by Öko-Institut¹⁴, are approximately \notin 60.000/MW.

 $^{^{10}}$ NOME, 2017, Joint Ministerial Decree AIIEHA/ $\Gamma/$ $\Phi1/178634,$ Official Government Gazette B2278/4.07.2017

¹¹ NOME, 2018, Joint Ministerial Decree ΑΠΕΗΛ/Γ/Φ1/176185, Official Government Gazette B2386/21.06.2018.

¹² NOME, 2019, Joint Ministerial Decree ΥΠΕΝ/ΔΗΕ/58239/1169, Official Government Gazette B2618/28.06.2019.

¹³ 2013, December 3. PPC announcement <u>https://bit.ly/31HPgdJ</u>

¹⁴ Öko-Institut (2017): "Die deutsche Braunkohlenwirtschaft. Historische Entwicklungen, Ressourcen, Technik, wirtschaftliche Strukturen und Umweltauswirkungen. Studie im Auftrag von Agora

The salaries of the miners and the associated administrative personnel were obtained from PPC's annual reports for 2016, 2017 and 2018. After subtracting the overtime payroll for the mines that were already accounted for in the variable costs, the fixed costs for the mines were calculated for each year. Dividing with the overall net capacity of PPC's lignite fleet yields the unit fixed costs in \notin /MW. The corresponding results are shown in Table 4. The fixed costs for the first semester of 2019, were assumed to be the average of the three previous years. Note that these estimates of the unit fixed mine costs are also far below the corresponding ones for Germany, which, according to Öko-Institut, reach 94.000 \notin /MW.

Unit fixed costs	2016	2017	2018	Average
fcm (€/MW)	49.015	56.725	56.353	54.031

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To find the monthly fixed costs for each unit, the two components were multiplied by the net capacity of each unit and the resulting annual fixed costs of the unit were divided by 12. PPC only knows the exact fixed costs per unit per year.

Results and Discussion

By implementing the model described above and the corresponding data, the gross profit of each unit and its fixed costs were computed for every month in the period January 2016-June 2019. Figure 1 shows the cumulative results for every one of the first semesters in the 42-month period under consideration.



Figure 1: Gross profits and half of the annual fixed costs for each Greek lignite unit during the first semesters of 2016, 2017, 2018 and 2019

The total gross profit of all Greek lignite units was estimated to be \in 33,8 million in the first semester of 2019, a 48% drop compared to the same period in 2018 (\in 62,9 million), and an 84% decrease compared to the first semester of 2017 (\in 200,7 million). The result is attributed primarily to the decreased electricity production in 2019 compared to 2018 and especially 2017, as well as to the escalation of carbon prices in 2019. The gross profit in the first semester of 2019 was slightly lower even compared to the same period in 2016 where both the electricity and carbon prices were much lower. However, the electricity production in the first semester of 2016 was almost 12% higher (6,5 TWh in Jan-Jun 2016 vs 5,7 TWh in Jan-Jun 2019).

With the exception of Amyntaio I, all other lignite units had a **smaller gross profit in January-June 2019 compared to the same period in 2018**. This is the result of a 16,1% drop in lignite-based electricity production between the two periods which led to a smaller revenue from electricity sales, in conjunction with an almost doubling of the CO_2 price (from 12,11 \in /tn on average in Jan-Jun 2018 to 23,77 \in /tn on average in Jan-Jun 2019).

January-June 2017 was the semester with the highest gross profits for Greek lignite units. Ag. Dimitrios I, Ag. Dimitrios IV and Kardia IV constitute the exception to this trend, due to the fact that these units practically did not operate during that period. However, all units that did produce significant amounts of electricity had a higher gross profit compared to all other first semesters. This can be understood if one considers the highest electricity production for almost all units during the first semester of 2017, the peak in electricity prices in January 2017 and the much lower CO_2 cost during Jan-Jun 2017 compared to the same period in 2018 and especially 2019.

Ag. Dimitrios I, Kardia I, Kardia II, Megalopoli III and Megalopoli IV had a negative gross profit in the first semester of 2019. For Ag Dimitrios I, Kardia I and Kardia II the result can be attributed to the fact that these units produced a small amount of electricity during the first semester of 2019; hence, the revenue from sales was not enough or barely enough to cover the increased CO_2 costs. This explanation does not apply to Megalopoli IV, which in the first semester of 2019 produced three times the electricity it produced during the same period of 2018 and had 3,5 times higher revenue from sales due to an increase in the electricity price as well. However, the increase in the electricity produced led to a disproportional increase in CO_2 emissions too, since Megalopoli IV has by far the greatest carbon intensity amongst Greek lignite plants (3-year average of 2,121 tnCO₂/MWh vs 1,577 tnCO₂/MWh average for all Greek lignite plants). The increase in CO_2 emissions in conjunction with the almost doubling of carbon prices between the first semesters of 2018 and 2019, led to an explosion of CO_2 costs for the unit, which were estimated to increase from approximately €3,9 million in Jan-Jun 2018 to almost €30 million in Jan-Jun 2019. A similar reasoning can be applied to explain the collapse in the gross profit of Megalopoli III from €5,5 million in Jan-Jun 2018 to -€6.304 in Jan-Jun 2019. In this case, as opposed to Megalopoli IV, the electricity production remained practically the same and the revenue from electricity sales increased by 27%, due to a similar increase in the electricity prices. However, the CO₂ costs more than doubled due to the doubling of the carbon prices in conjunction with the fact that Megalopoli III has the second highest carbon intensity amongst Greek plants. The increase in carbon costs, in turn, led to the collapse in the gross profit of the unit. In summary, the negative gross profits for Megalopoli IV and Megalopoli III can be characterized as more "systemic" when compared to the negative gross profit of Ag. Dimitrios I, Kardia I and Kardia II, which were mainly attributed to decreased electricity production.

Meliti had the largest gross profit in January-June 2019. This can be attributed to the fact that this unit has a significantly smaller carbon intensity compared to the other Greek lignite unit (1,276 tn CO_2/MWh average for Meliti vs 1,577 tn CO_2/MWh average amongst all lignite plants in the period 2016-2018). However, the unit's half-year fixed costs were higher, thus resulting to a ϵ 6,2 million net loss during the first semester of 2019 despite the fact that Meliti is the most efficient and less carbon intensive lignite unit in Greece.

Ag. Dimitrios V had the largest gross profit amongst the 4 first semesters under consideration, which occurred in Jan-Jun 2017. During that period, the unit produced the most electricity than any other unit in any of the other 3 first semesters (2016, 2018, 2019), while the average electricity price was the second highest (57,7 \in /MWh) and the carbon prices were still low; thus, resulting to the highest estimated gross profit.

Only during the first semester of 2017, 9 out of the 14 lignite units had a gross profit that was greater than the corresponding fixed costs. Still, that was not enough for the lignite industry to be profitable since all Greek lignite units cumulatively produced a net loss of around €7,6 million. In every month of the other three first semesters (2016, 2018, 2019), the gross profits of all lignite units was smaller than half of the annual fixed costs, thus leading to net losses far more significant than those of 2017.



Figure 2 shows the cumulative estimates for the gross and net profits of all Greek lignite units as a function of time.

Figure 2: Cumulative gross and net profits of all lignite plants for the period January 2016-June 2019

Overall, in all four first semesters of 2016-2019 the aggregate fixed costs for all Greek lignite units were greater than the aggregate gross profits, leading to net losses of €153 million, €7,6 million, €144,7 million and €170 million, in the first semesters of 2016, 2017, 2018, and 2019, respectively. It is estimated that over the entire 42-month period from January 2016 until June 2019, PPC has accumulated a net loss of €683,7 million from the operation of its lignite units. This amount is directly comparable with the €600 million which PPC lost due to the NOME auctions during the same period, according to the new Minister of Environment and Energy^{15,16,17}.

The model estimates that the **Greek lignite units produced net profits only in 5 out of the 42 months of the period under examination**, with the biggest occurring in January and November 2017, when the electricity prices peaked at $91,9 \in /MWh$ and $80 \in /MWh$, respectively.

The lignite industry is accumulating net losses every month since December 2017, even in months where demand is peaking such a July and December. The trend of escalating net losses has been deteriorating in 2019. May, June and March 2019 were the worst 3 months in the last 3,5 years with estimated net losses of \in 35,3, \in 34,9 and \in 34,1 million, respectively. Also during these three months, the lignite industry overall had negative gross profits, a phenomenon that was observed for the first time in the 3,5 year period under examination

¹⁵ 2019, August 2. Press Release by the Ministry of Environment and Energy <u>https://bit.ly/20ZydT8</u>

¹⁶ 2019, August 1. Press Release by the Ministry of Environment and Energy <u>https://bit.ly/2YR2aco</u>

¹⁷ 2019, July 26. Press Release by the Ministry of Environment and Energy <u>https://bit.ly/2N3NRKx</u>

A better understanding of the results presented so far can be obtained by comparing the two most significant parameters influencing the gross profits of the lignite units, namely, the electricity prices and the carbon prices. Given that the variable cost (excluding the CO_2 cost) remained practically the same in the period under consideration, the difference between the electricity and the carbon prices, largely determines the gross profitability of the lignite units.

For comparison purposes, the carbon prices were converted to \notin /MWh by multiplying the CO₂ costs (in \notin /tn CO₂) with the average carbon intensity of all Greek lignite units over the 3-year period 2016-2018 (in tn CO₂/MWh). The results of this comparison are shown in figure 3.



Figure 3: Electricity prices, average CO_2 costs and their difference as a function of time.

The CO₂ costs have more than quadrupled, almost monotonically, from less than $10 \notin /MWh$ in early 2016 to more than $40 \notin /MWh$ in mid 2019. On the other hand, the electricity prices exhibited fluctuations with 3 peaks in January 2017 (91,9 €/MWh), November 2017 (80 €/MWh) and January 2019 (81,1€/MWh). The lowest electricity prices were observed in the first semester of 2016 (minimum 41,23 €/MWh in April 2016), whereas the prices in the first semester of 2019 varied between 65 €/MWh and 81 €/MWh with an average of 71,1 €/MWh.

One can further observe that during the period when the carbon prices were relatively low (below 15 \in /MWh), up until February 2018 approximately, the difference between the electricity and carbon prices, followed closely the trend of the electricity prices. However, starting March 2018 when the carbon price rally began, the difference between electricity and carbon prices begin to diverge. In particular, despite rising electricity prices, the difference started to gradually decrease to around 30 \in /MWh, which is slightly higher than the variable costs; thus, shrinking the gross profits of Greek lignite units.

Finally, it is also evident that electricity prices in Greece are significantly influenced by carbon prices since the recent rise of the average electricity prices correlates with the corresponding increase in carbon prices. In fact, using data from ENTSO-E, Sandbag¹⁸ calculated that the day-ahead electricity prices in Greece increased by 26% between the first semesters of 2018 and 2019, the third largest increase in the EU after Romania (33%) and Bulgaria (32%). **The high impact of carbon prices on electricity prices in Greece is a consequence of the still significant dependence of the electricity mix on lignite, which has by far the highest carbon intensity in the EU. However, we note that the carbon price is not the only factor affecting electricity prices in Greece as can be observed in Figure 3 by the fact that spikes in the electricity prices in the carbon prices.**

¹⁸ 2019, July. Sandbag. "The Great Coal Collapse of 2019. Mid year analysis of the EU power sector" <u>https://sandbag.org.uk/project/coal-collapse/</u>

Future Scenarios and Outlook

As seen in figure 2, starting March 2019, the cumulative gross profit of Greek lignite units has shrunk to unprecedented lows leading to record net losses. In fact, the gross profit of Megalopoli III and Megalopoli IV was estimated to be negative during the first semester of 2019. Also, the gross profit of the lignite industry overall was estimated to be negative in March, May and June 2019, a phenomenon that was observed for the first time in the 42-month period under consideration. These results were attributed to the skyrocketing of carbon prices which could not be counteracted by the smaller increase in electricity prices during the same period (see figure 3). Bearing in mind that according to analysts this trend is expected to intensify in the coming years, it is important to understand its impact on the economics of the Greek lignite industry.

To address this challenge, we developed 4 scenarios and the gross and net profits were calculated for each of them for the next 3,5 years (July 2019-Dec 2022), using the abovementioned model. The revenue of the lignite units was approximated by multiplying the electricity price with the amount of electricity produced, both of which were parameters in the calculations. The first scenario considered is a continuation of the current state as it is defined by the results of the first semester of 2019, while the other three scenarios include reductions in the lignite capacity. The main parameters that were used in the 4 scenarios are shown in Table 5.

Parameter	7-12/2019	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Net capacity (MW)	3904	3904	2256	1708	1452
Electricity (MWh)	6.756.978	12.500.017	12.500.017	10.392.348	9.539.640
Electricity price (€/MWh)	76,89	78	78	78	78
Carbon price (€/tn)	29,03	31 ± 20%	31 ± 20%	31 ± 20%	31 ± 20%

Table 5: Parameters used in the estimations for the period 7/2019-12/2022

For all scenarios, the average electricity price for 2020 and beyond was chosen to be 78 \notin /MWh, and the nominal carbon price was taken to be 31 \notin /tn CO₂ according to the estimates recently made by PPC in its effort to sell part of its lignite assets to private investors¹⁹. To assess the effect of the inherent uncertainty in carbon prices we also considered prices 20% above and below the nominal value. Note that this range incudes the lower estimate by PPC of 27 \notin /tn CO₂, as well as the average prediction of 34,37 \notin /tn CO₂ by 8 analysts polled by Reuters for 2020²⁰. The lower part of the range value can also be viewed as equivalent to having an average price of 31 \notin /tn CO₂, but managing to shave off 20% of the carbon costs by implementing a successful hedging strategy.

Table 5 also shows the corresponding parameters for the 2^{nd} semester of 2019, which were common in the calculations for all 4 scenarios. These were chosen so that: a) the annual lignite-based electricity production for 2019 is 16,1% lower than that of 2018 (i.e. 12,5 TWh) following the trend of the first semester of 2019; b) the average carbon price to be such that the annual average is in agreement with the analysts' prediction for 2019 (i.e. $26,4 \in/tn$); c) the average electricity price is equal to the lower end of PPC's estimate (i.e. $74 \in/MWh$).

¹⁹ 2019, May 22. Article in energypress.gr <u>https://bit.ly/20Ta14K</u>

²⁰ 2019, July 12 Reuters. "Analysts increase EU carbon price forecasts, short-term Brexit risks remain -Reuters poll" <u>https://reut.rs/2Un30gp</u>

The assumptions of the 4 scenarios that were analyzed, as well as the rationale in constructing them are described in the following:

Scenario 1 (BaU): This scenario can be viewed as Business As Usual (BaU) since the overall net capacity of lignite units remains the same (3.904 MW), while the electricity produced for the entire period is assumed to follow the results of the first semester of 2019, that is, on an annual basis it is taken to be 16,1% lower than the 2018 production.

Scenario 2 ("-Kardia/Amyntaio"): Same as scenario 1 but with a reduced lignite capacity resulting from the retirement of TPS Kardia and TPS Amyntaio. This choice is dictated by the fact that both units have exhausted the 17.500 operating hours that were granted to them according to article 33(1) of the Industrial Emissions Directive (2010/75/EE). In fact, the European Commission has sent to Greece a letter of notice related to the fact that the previous Greek government has issued two ministerial decrees (one for each plant) unilaterally interpreting the IED in order to extend the operational life of TPS Amyntaio, TPS Kardia III and TPS Kardia IV to 32.000 hours. Therefore, the retirement of both plants is predominately an issue of respecting and complying with the European environmental legislation. Furthermore, both of these plants are amongst the most polluting in the EU. In particular, TPS Amyntaio emits on average 8,1 and 4,2 times above the European emission limit values for SO₂, and PM, respectively, whereas Kardia I, II, III, and IV emit on average 15,7, 17,3, 4,1 and 3,5 times above the European emission limit value for PM, respectively. Therefore, the retirement of these plants will vastly improve air quality for citizens of Greece and neighboring countries. From the financial perspective, the retirement of the Kardia and Amyntaio units will significantly reduce the fixed costs; thus, improving the overall economics of the Greek lignite industry.

In this scenario, the overall electricity produced by the remaining lignite units was assumed to be the same as in scenario 1. The corresponding electricity that will be lost by the retirement of Kardia and Amyntaio will be provided by the remaining lignite units in Western Macedonia, which have enough capacity to perform the task. Specifically, assuming a drop of the lignite-based electricity production of 16,1% in 2019 compared to 2018 for each unit (i.e. 12,5TWh overall), the electricity estimated to be produced by Kardia and Amyntaio in 2019 will be approximately 4TWh. This electricity can be covered by the remaining Ag. Dimitrios and Meliti units, which will lead to an increase in their combined capacity factor from 39,2% in 2019 to 65,2% in the following years.

Scenario 3 ("–Ag.Dimitrios I-II"): Same as scenario 2 but with a further decrease in the overall capacity due to the retirement of Ag. Dimitrios I and II units. These units are old (both 35 years old in 2019) and are the biggest NOx emitters in Greece emitting more than twice above the European emission limit value. Moreover, they are not connected to the district heating system for the city of Kozani. Thus, their retirement will provide a significant reduction in the fixed costs without a major drop in the overall electricity produced by the remaining 3 Ag. Dimitrios units and Meliti I and without inhibiting Kozani's district heating system. Furthermore, all lignite plants need to comply with the new limits of the BATc by August 2021 at the latest. Since the stack of Ag. Dimitrios I –II emits on average considerably above the limits for all three major pollutants (2 times above the NO_x limit, 2,3 times above the SO₂ limit and 2,6 times above the PM limit), significant retrofits will be required for compliance with the new BATc. Hence, ceasing the operation of these units will help PPC avoid the costs for installing the appropriate abatement technologies.

Ag. Dimitrios III, IV, V and Meliti I cannot cover the electricity estimated to be produced by TPS Kardia, Amyntaio as well as Ag. Dimtrios I-II in 2019. Thus, in this scenario, a decrease in the overall electricity produced by lignite units will be assumed for the following years. In particular, if the 4 remaining units in W. Macedonia are assumed to operate with a combined capacity factor of 75% and the 2 units in Megalopoli as they operated in 2019, the overall electricity produced by lignite units will be reduced to 10,4TWh for the period 2020-2022.

Scenario 4 ("–Megalopoli IV"): Same as scenario 3, but with further decrease in the overall capacity due to the retirement of Megalopoli IV. This unit has by far the highest carbon intensity and hence, is the most vulnerable amongst all units with respect to increases in carbon prices. As shown earlier, the unit was estimated to exhibit a negative gross profit in the first semester of 2019, a situation that is expected to deteriorate with increasing carbon prices.

The remaining lignite unit in Peloponnese (Megalopoli III), which is expected to operate in 2019 with a capacity factor of 54,5% cannot cover the entire amount of electricity estimated to be produced by Megalopoli IV in 2019 (1,311 TWh). Thus, assuming that in the absence of Megalopoli IV, Megalopoli III will have a capacity factor of 75%, the overall lignite-based electricity in this scenario will drop to 9,5 TWh in 2020 and 2021.



Figure 4: Cumulative estimated gross profits, net profits and fixed costs for Greek lignite units for the period July 2019-December 2022 under 4 scenarios. The first data point for the gross profit, net profit and fixed costs lines shows the corresponding results for the preceding 3,5 year period (January 2016-June 2019. The shaded bands around the gross profit and net profit lines correspond to calculations with carbon prices 20% below (upper bound) and 20% above (lower bound) the nominal value.

Figure 4 shows the estimates of the gross and net profits for each scenario as well as the corresponding fixed costs for the Greek units and for the next 3,5 years (July 2019-December 2022). For comparison purposes, the corresponding cumulative results of the preceding 3,5 year period (January 2016-June 2019) that were presented earlier are also shown as the first data point in each of the three curves. Moreover, in the same plot we also show the effect of the

most significant parameter influencing the gross and net profits, namely the carbon price. One can observe the following:

No scenario of those examined leads to a net profit for the Greek lignite industry in the next 3,5 years. This finding clearly underlines the dire financial situation PPC finds itself in. It is true even if PPC manages to shave off part of its CO_2 costs through the implementation of a successful hedging strategy; it is true even if the carbon prices are 20% lower than the nominal value of 31€/tn. If, on the other hand, carbon prices rise above approximately 33 €/tn, then the Greek lignite units will produce, on aggregate, negative gross profits. If such a situation occurs then from a purely financial perspective, PPC's interest is better served by ceasing the operation of its lignite fleet, while continuing to pay all employees in the mines and the units.

However, there are major differences amongst the four scenarios. Specifically:

The BaU scenario where current lignite capacity remains in operation for the coming years may lead to an explosion of net losses to more than €1.3 billion or even €1.7 billion in case carbon prices surpass the 37€/tn threshold. This increase in the net losses by more than €600 million compared to the previous 3,5 year period, is a direct consequence of the skyrocketing carbon prices increasing by almost a factor of 3 (from an average of 11 €/tn in the previous 3,5 years to 30,3€/tn in the upcoming 3,5 year period), which cannot be counterbalanced by just a 35% increase in electricity prices (from an average of 57,6 €/MWh in the previous 3,5 years to 77,8€/MWh in the upcoming 3,5 year period).

The scenario where Kardia and Amyntaio retire in the coming months, offers a significant improvement compared to BaU. The overall fixed costs are reduced by more than 42%, while keeping the revenue from electricity sales the same, since the electricity previously produced by Kardia and Amyntaio is provided by the remaining units in W. Macedonia. The overall net losses in the nominal case of this scenario are estimated to drop to \notin 793 million over the period Jul 2019-Dec 2022, close to the net losses accumulated during the last 3,5 years (\notin 683 million). However, the improvement of this scenario, is that it manages to keep the net losses at similar levels as in the previous 3,5 years under a severe increase in the CO₂ costs.

Further improvement can be achieved by retiring also Ag. Dimitrios I-II units. Despite the fact that the revenue of electricity sales in this scenario drops due to the reduction in overall electricity production compared to scenarios 1 and 2, the accompanying drop in fixed costs is more significant, thus, leading to a 20% reduction in net losses compared to scenario where only TPS Kardia and TPS Amyntaio are retired (€637 million cumulative net losses in the scenario "-Ag. Dimitrios I-II" vs €793 million in the "-Kardia/Amyntaio" scenario). Comparing the net losses in this scenario with those of the previous 3,5 years, it becomes evident that **the retirement of TPS Kardia, TPS Amyntaio and TPS Ag. Dimitrios I-II is almost counterbalancing the tripling of the carbon prices between the two periods**. The improvement resulting from the early retirement of Ag. Dimitrios I-II would be even bigger if one takes into account the avoided costs for the retrofit of the two units in order to comply with the new European emission limit values.

The fourth scenario "-Megalopoli IV" provides the best economic performance amongst all scenarios, with a further 11,6% decrease in the cumulative net losses compared to the "-Ag. Dimtrios I-II" scenario. Despite the 8% decrease in the lignite-based electricity production and, hence, the revenue from electricity sales, the additional retirement of the most carbon intensive unit in the Greek lignite fleet slashes the annual net losses to less than €130

million, which is almost 3 times less than the \notin 377 million of annual net losses in the BaU scenario.

An added advantage of reducing the electricity production in Scenarios 3 and 4 is that the sensitivity of the gross and net profits to carbon prices decreases, as is evident by the reduced width of the two bands in figure 4. This can also be easily understood through eqs. (1)-(3), which show that the sensitivities of gross and net profits with respect to carbon prices are proportional to the electricity produced.

Conclusions and Policy Recommendations

The effect of lignite mining and burning on the climate, the quality of air, the natural resources and public health has been well-known for years. However, its use for electricity production in Greece has been tolerated by governments because lignite is an indigenous source of energy and produces cheap electricity.

The results presented in this report show that the argument that lignite-based electricity production is cheap has ceased to be true for several years. It was estimated that **during the 3,5 year period from January 2016 until June 2019, PPC has accumulated a net loss of €683 million from the operation of its lignite units**. This amount is directly comparable with the €600 million which PPC lost due to the NOME auctions during the same period.

Our analysis further shows that **if the current lignite fleet remains as is, then in the next 3,5 years, the situation will deteriorate and the lignite industry will accumulate losses of the order of €1,3 billion**. Therefore, in addition to protecting the climate, nature and public health, the retirement of lignite units is also dictated by purely financial reasoning and in the context of salvaging PPC, the largest publicly owned company in Greece, which currently finds itself in the worst financial state of its history.

Specifically, **the immediate retirement of TPS Kardia and TPS Amyntaio is highly recommended** since it will vastly improve the economics of PPC by slashing the lignite-fleet's projected net losses by over €600 million in the next 3,5 years. Such a decision will not require any reduction in the overall lignite-based electricity production, since the electricity produced by the two plants could be replaced by the remaining lignite units in W. Macedonia. Therefore, the retirement of the two plants does not pertain to any issues of security of electricity supply. This is also consistent with the most recent resource adequacy assessment by ADMIE²¹, which had factored in the retirement of the Amyntaio I-II and Kardia III-IV units by the end of 2019, due to the exhaustion of the 17.500 operating hours made available to them through the Industrial Emissions Directive, and that of Kardia I-II units by early 2020.

Provided that 3 TWh of electricity per year can be produced by other sources of energy, **the additional retirement of the Ag. Dimitrios I-II and Megalopoli IV units is also recommended**, since it will bring down the annual net losses of Greece's lignite industry to the levels of \notin 130 million, a 66% improvement compared to the scenario where no retirement takes place.

The results presented in this report show that the economics of Greek lignite units are and will continue to be prohibitive for potential investors. Given the net losses they will continue to generate, they can only attract investors if the lignite industry is supported with additional subsidies. However, such subsidies will come at the expense of the Greek electricity consumers, while also undermining the necessary shift of Greece's electricity model towards renewables. Therefore, it becomes clear that **future efforts to reform Greece's electricity market should abandon any attempts to sell PPC's lignite assets or further subsidize the Greek lignite industry through derogations of the European environmental legislation.**

²¹ 2017, May. ADMIE Resource Adequacy Assessment for the period 2017-2027 <u>https://bit.ly/2H6VBb5</u>

Moreover, bearing in mind that the EU climate and environmental policies are rapidly becoming more ambitious, the situation will become even tighter in the near future for the lignite industry. It is inconceivable that in such an environment, PPC will continue to move forward with the new lignite project "Ptolemaida V". It is therefore recommended that **PPC carefully examines all possible, alternative uses for Ptolemaida V** in collaboration with the construction company, the government and the institutions financing this project.

The findings of this report also illustrate the dire **need for updating Greece's current draft for the National Energy and Climate Plan** (NECP). Specifically, the draft NECP proposes a 9,5 TWh lignite-based electricity production in 2030 by a 2,7 GW lignite fleet (with all accompanying fixed costs), while this report shows that the **economic rescue of PPC is tightly related to having the same levels of electricity production 10 years earlier, while maintaining a much smaller lignite fleet with less than 1,5 GW of net lignite capacity**.

Despite significant differences between the different scenarios constructed and analyzed in this report, it was found that **no scenario can lead to a net profit of the Greek lignite industry in the next 3,5 years**. On the contrary, there is a distinct possibility that these predictions may be even worse. Hence, more than any other country in the EU, it is imperative for **Greece to commit to a specific retirement schedule of all lignite units until 2030 at the latest.** The recommendations for lignite unit retirements made in this report may contribute towards identifying the units that need to retire first at an early date, in order to address the urgent problem of improving the dismal financial state PPC finds itself in currently.

Leaving behind its lignite past in an organized and well-planned way is a prerequisite for transforming PPC into a sustainable, financially healthy company. A lignite phase-out plan will boost the commitment of national, regional and local authorities towards a just transition of the lignite-dependent regions to alternative sustainable activities and will provide Greece the opportunity to transition to a climate neutral future.

