WWF

BRIEFING PAPER

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Ptolemaida 5 and Meliti 2

Economic viability report of the new lignite units

CONTENTS

INTRODUCTION

Aim of the report

On 29th March 2013, the General Meeting of the Greek Public Power Corporation SA (PPC) approved the signing of the construction contract for the new 660MW lignite unit Ptolemaida-5, which is expected to run in 2020. It will be the first lignite unit to be built in Greece since 2002, when the 450MW Meliti unit in Florina (Western Macedonia Region) came into operation. According to the investment plan of the PPC, a competition for selecting the constructor of an additional 440MW lignite unit in Meliti (Meliti-2) is also due, with the estimated operation date being 2021.

This study aims to examine the economic sustainability of the above units. The analysis was conducted for an economic timeline of 30 years and was based on the Electricity System development scenarios, presented by the Ministry of Environment, Energy and Climate Change (MEECC) in Greece's Energy Roadmap to 2050.

Structure of the report

The first part of the study is an introduction to the latest climate change findings, international decisions and strategies for moving to a zero emissions power system by 2050 and international tendencies and experiences in that direction.

The next part contains an overview of the Greek power system and the MEECC scenarios and assumptions for its future development. Next, the results of the economic analysis of Greece's lignite units are presented, with the methodology used described in Appendix A.

The final two sections are concerned with the local dimensions and consequences of the lignite "monoculture" in Western Macedonia. More specifically, the impacts on air quality, public health and water reserves are presented, along with a short description of settlement relocations resulting from the expansion of lignite mines in the region. The study of Greece's Technical Chamber (TCG) on the transition cost of the area towards a post-lignite future is critically evaluated, followed by a brief review of international experience on boosting employment through investments in energy efficiency and renewable energy sources (RES).

The Appendix includes the following:

- A description of CO_2 capture, transport and storage (CCS) technology, of the related European legislation and of a PPC study regarding its future use in the Ptolemaida-5 unit
- A discussion on the PPC's intention to attract favourable financing mechanisms from the international market
- A review of the position of the region's Local Councils regarding Ptolemaida-5 and the expansion of the lignite mines

Data and information used

First, it should be noted that, on 25.09.2012, WWF Greece made an official request to Greece's Regulatory Authority for Energy (RAE) to obtain access to the documents related to the environmental and economic sustainability of the Ptolemaida-5 unit, contained in the application submitted by the PPC. The Authority replied after 4 months, despite its obligation to do so within 20 days and did so, after WWF Greece had made public RAE's 'silent refusal' to respond to the request. As the information provided was not complete, WWF Greece made a second request to access the environmental information. This time the reply was on time, however access was provided to only part of the documents.

The techno-economical analysis conducted for the needs of this report, was based on the most accredited information available, and more specifically:

- The development scenarios for power demand, installed RES capacity and CO_2 emissions rights cost, as described in Greece's Energy Roadmap to 2050
- Data for the mining costs and calorific value of lignite, based on recently published information and estimates
- The expected price trajectory of natural gas based on the European Commission's projection studies.

Any other techno-economic information used was based on national and international literature, provided in the related references.

CLIMATE CHANGE FACTS

2012 saw an increase in the consensus amongst scientists that climate change is taking place and that further delays in drastically reducing greenhouse gas emissions, mainly related to electricity generation, will have unprecedented consequences on human life in the decades to come.

The climate is changing

The World Meteorological Organization (WMO) announced[1] in 2011 that the average CO_2 concentration in the atmosphere had reached 390.9ppm (parts per million), showing a 40% increase compared to CO_2 levels at the beginning of the industrial era 250 years ago (280ppm). Following the current increase rate of 2ppm per year, it is expected that, by 2015, CO_2 levels will have reached 400ppm, which scientists consider the safety benchmark for avoiding climate destabilisation. A particularly alarming indication is that for the first time in history, an average daily CO_2 concentration of 400.17ppm was registered at NOAA's observatory in Mauna Loa, on 13 May 2013. According to scientists, the last time the concentration of the Earth's CO_2 reached that level was in the Pliocene Epoch, between 3 and 5 million years ago.

Global warming is an undisputable fact. 2012 has been the 9th warmest year on record, while 9 out of the 10 warmest years in history have all occurred in the 21st century.[2] Breaking every record, the Arctic minimum ice extent was 760km^2 less than the previous low, set in 2007.[3]

In a related study, the Berkeley Earth Project gathered historical data of 14.4 million temperature records from 44,455 different locations on the planet, with the first estimates extending back to 1753. The analysis shows that the rise in average global land temperature is approximately 1.5^{o}C in the past 250 years and about 0.9 degrees in the past 50 years.[4] The report emphasises that "*humans are almost entirely the cause*" for global warming, having concluded that solar variation had no effect and that volcano activity had only a minor impact in the 20th century.

In its annual report[5], the European Environment Agency (EEA) observed that climate change is already affecting all European regions and that more costly impacts should be expected in the future. More specifically, the European land temperature was 1.3°C warmer than the pre-industrial average, heat waves have increased in frequency and length, river flooding has increased in northern Europe and minimum river flows have decrease in southern Europe.

The World Bank review of the latest climate science[6] concludes that, if no action is taken against climate change, the average global temperature will increase by 4°C by the end of the century. Such an event will trigger coastal zone erosions and destruction, increased malnutrition rates as a result of impacts on agriculture, many dry regions becoming dryer and

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[1] WMO, "Greenhouse Gas Concentrations Reach New Record", 20.11.2012 http://www.wmo.int/pages/mediacentre/press_releases/pr_965_en.html

[2] NASA, "NASA Finds 2012 Sustained Long-Term Climate Warming Trend", 15.01.2013 http://www.nasa.gov/topics/earth/features/2012-temps.html

[3] NASA, "Arctic Sea Ice Hits Smallest Extent In Satellite Era", 19.09.2012 http://www.nasa.gov/topics/earth/features/2012-seaicemin.html

[4] Berkeley Earth Project, Summary of results http://berkeleyearth.org/results-summary/

[5] EEA, "Climate change evident across Europe, confirming urgent need for adaptation", 06.02.2013 http://www.eea.europa.eu/pressroom/newsreleases/climate-change-evident-across-europe

[6] World Bank, "New Report Examines Risks of 4 Degree Hotter World by End of Century", 18.11.2012 http://www.worldbank.org/en/news/press-release/2012/11/18/new-report-examines-risks-of-degree-hotter-world-by-end-of-century

wet regions wetter, unprecedented heat waves, increased intensity of tropical cyclones and irreversible loss of biodiversity, including coral reef systems.

These developments don't concern only the far future. A number of studies have found that the increased intensity and frequency of extreme weather events all around the world is linked to global climate destabilisation, which is already on course.

A statistical analysis of temperatures of the last 60 years conducted by NASA's Goddard Institute for Space Studies (GISS)[7] revealed that the Earth's land areas have become much more likely to experience an extreme summer heat wave than they were in the middle of the 20th century, as a result of climate change. Moreover, a Potsdam Institute study[8] found that there are now five times as many record-breaking hot months worldwide than could be expected without long-term global warming. In accordance with the above, Australia's Climate Change Commission concluded that the extreme heat waves and catastrophic bushfire conditions during the 2012/13 summer were made worse by climate change and that it is highly likely that extreme hot weather will become even more frequent and severe over the decades to come[9].

Finally, as far as rainfalls are concerned, according to a newly-published study of the NOAA (National Oceanic and Atmospheric Administration), the extra moisture in the atmosphere due to global warming will lead to a 20-30% increase in extreme rainfall events in the Northern Hemisphere.[10] At the same time, a study published in the scientific journal of the USA's National Academy of Sciences revealed that a 1 °C rise in global temperature will lead to a twofold to sevenfold increase in the frequency of Katrina-magnitude events in the Atlantic. [11]

Addressing climate change

The scientific community has made clear that the only way to avoid the worst consequences of climate change is the drastic and immediate reduction of greenhouse gas emissions globally, especially CO_2 which is mainly the result of burning fossil fuels.

Realising the importance of this challenge, – at least on the level of stated claims– the world's government representatives declared in a UN conference held in Doha on 8th December 2012 that "*they will urgently work towards the drastic reduction in global greenhouse gas emissions required to hold the increase in global average temperature below 2 °C above pre-industrial levels and to attain a global peaking of global greenhouse gas emissions as soon as possible*".[12]

As for the required emissions reduction for achieving such a target, the most accredited estimate comes from the latest report of the **Intergovernmental Panel on Climate Change (IPCC)** in 2007.[13] According to its findings, in order to stabilize the global mean

[7] NASA, "Research Links Extreme Summer Heat Events to Global Warming", 08.06.2012 http://www.nasa.gov/topics/earth/features/warming-links.html

[8] Potsdam Institute for Climate Impact Research, "Global warming has increased monthly heat records by a factor of five", 14.01.2013 http://www.pik-potsdam.de/news/press-releases/monatliche-hitzerekorde-haben-sich-durch-die-erderwaermung-verfuenffacht

[9] The Climate Commission (Australia), "The Angry Summer" http://climatecommission.gov.au/report/the-angry-summer/

[10] Kenneth E. Kunkel et al. "Probable maximum precipitation and climate change", 12.04.2013, http://www.noaanews.noaa.gov/stories2013/20130403_ncdcextremeprecipitationstudy.html

[11] Aslak Grinsted et al. "Projected Atlantic hurricane surge threat from rising temperatures" , 23.05.2013, http://www.pnas.org/content/early/2013/03/14/1209980110

[12] UNFCCC, "Report of the COP-18 sesssion, held in Doha from 26 November to 8 December 2012", 28.02.2013 http://unfccc.int/resource/docs/2012/cop18/eng/08a01.pdf

[13] IPCC, Fourth Assessment Report: Climate Change 2007: Working Group III: Mitigation of Climate Change: D. Mitigation in the long term (after 2030) http://www.ipcc.ch/publications_and_data/ar4/wg3/en/spmsspm-d.html

temperature increase at 2.0-2.4°C, which corresponds to an equivalent CO_2 concentration of 350-400ppm, the global CO_2 emissions need to reach their peak before 2015 and decline by 50-85% by 2050.

These findings have been confirmed by practically all the scientific studies that followed. The most prominent one, published in Nature magazine in 2009,[14] estimated that in order to achieve the 2°C target with a 75% probability, we can afford to burn less than half of the already known fossil fuel reserves. It was also calculated that a 50% reduction of global emissions by 2050 yields a 55-88% probability of achieving the target, dropping to 46% if global emissions are 25% higher in 2020 compared to 2000 levels.

The United Nations Environment Programme (UNEP) recently announced[15] that there is a gap of 8 Gt of CO_2 equivalents between the maximum emissions allowed in 2020 in order to prevent a major climate destabilisation, and those expected to be achieved even if all national emission commitments are fulfilled. That means that global emissions, already increased by 25% over the past decade, need to be reduced by at least 12% until 2020.

The same conclusion is drawn from other recent important scientific studies. According to a study published in Nature magazine[16], in order to stabilize the global mean temperature increase at 2°C, global emissions need to decrease by 10-21% by 2020, compared to 2012 levels. Another study also published in Nature magazine[17], concludes that in order to retain a 50% probability for the 2°C target, global CO_2 emissions need to reach their peak by 2016 and thereafter follow a 5% annual decrease rate until 2050, a development that will reduce climate change impacts by 20-65% by 2100, compared to the estimated temperature increase of 4°C described in the reference scenario.

It has also been made clear that any delay in taking ambitious action at a global level will multiply the costs of addressing climate change.[18] For example, assigning today a global price of $20 per ton of CO_2 emitted would translate to a 60% possibility of stabilising the global mean temperature increase at 2°C. However, if action is taken in 2020, in order to achieve the same target, a price of $100 per ton of CO_2 emitted would be required.

Special mention should be made of the annual report of the International Energy Agency (IEA) "**World Energy Outlook**".[19] One of the main findings of the study is that, in order to stabilise the global mean temperature increase at 2°C, only 1/3 of the already known fossil fuel reserves can be burned by 2050. More specifically, humankind has at its disposition a "carbon budget", i.e. an emissions margin, of 1,000 billion tonnes of CO_2, in order to prevent climate destabilisation. Given that burning of all the confirmed oil, coal and natural gas reserves will lead to 2,860 billion tonnes of CO_2 emitted, it is concluded that almost 2/3 of these reserves should either not be extracted or they should be burnt using the – neither proven nor competitive for the time being –CCS technology. The other major and alarming conclusion of the study is that 4/5 of the allowed emissions till 2035 are already locked-in due to the operation of existing infrastructure (power stations, factories, buildings etc).

Examining the global energy scenarios towards 2050 and their significance regarding the climate, the IEA report emphasises that even in the "new policies" scenario, the possibility of stabilising the global mean temperature increase at 2°C is only 6%, with the most likely

[14] Meinshausen et al, "Greenhouse-gas emission targets for limiting global warming to 2 °C" http://www.nature.com/nature/journal/v458/n7242/full/nature08017.html

[15] UNEP, "Greenhouse Gas Emissions Gap Widening as Nations Head to Crucial Climate Talks in Doha", 21.11.2012 http://www.unep.org/newscentre/Default.aspx?DocumentID=2698&ArticleID=9335&l=en

[16] Joeri Rogelij et al., "2020 emissions levels required to limit warming below 2C", 05.07.2012, http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate1758.html

[17] http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate1793.html

[18] J. Rogelj et al, "Probabilistic cost estimates for climate change mitigation", Nature 493, 79–83 (03 January 2013) http://www.nature.com/nature/journal/v493/n7430/full/nature11787.html

[19] IEA, World Energy Outlook 2012, 12.11.2012 http://www.worldenergyoutlook.org/publications/weo-2012/

increase being 3.6°C. The only scenario of the study that meets the 2°C target is that of stabilizing CO_2 concentration at 450ppm, which requires far more ambitious policies with regards to fossil fuel exploitation. For instance, in this scenario lignite consumption corresponding to the OECD countries drops from 198 million tonnes in 2010 to 41 million tones in 2035, i.e. an 80% reduction.

The impact and cost of climate change in Greece

Climate Change does not concern only the Arctic or Africa's and Asia's vulnerable countries, but Greece as well.

In September 2009, WWF Greece and the National Observatory of Athens published the scientific study **"The future of Greece: climate change impacts in Greece for the near future"**.[20] According to the findings of the study, cities such as Thessaloniki, Patras, Lamia and Larisa will have 20 more days of heatwaves and a subsequent increase in risk of fire occurrence in suburban forests. At the same time, the total annual precipitation will be reduced, but extreme rainfall and floods are expected to increase by 20%. Such a future will have unpredictable impacts on two of the most pivotal sectors of economic activity in Greece: agriculture and tourism.

In June 2011, the Bank of Greece, after two years of research, published the report **"The Environmental, Economic and Social Impacts of Climate Change in Greece"**.[21] The report stresses, amongst other things, that the 1,000 km coastline of the country is highly vulnerable to climate change (by the end of the century, the decrease in precipitation levels will range between 5% and roughly 19%) and that there will be 35-40 more days of a maximum daily temperature of 35°C or more compared to today.

Apart from the environmental impacts, the report predicts a huge economic cost of climate change on Greece. In the worst case scenario, the total cumulative cost for the Greek economy by 2100, would amount to €701 billion (using fixed prices of 2008), which is more than double Greece's national debt in 2009. The report points out that the adoption of climate change policies is the best economic choice available: in the Mitigation Scenario, which assumes that Greece will achieve a consistent and drastic reduction in greenhouse gas emissions in parallel with a broader global effort, the total cost for the economy amounts to €436 billion, i.e. €265 billion less than under the Inaction Scenario.

More recently, in December 2012, the National Observatory of Athens published updated estimates, which are also presented in the new section of OIKOSKOPIO, WWF Greece's online mapping application for the environment of Greece.[22] These estimates predict that between 2021 and 2050 there will be a 50% increase of hot days in Greece, rising to 100% between 2071-2100, as well as 30 more days of increased risk of fire occurrence per annum.

[20] WWF, "The future of Greece: climate change impacts in Greece for the near future", September 2009, http://www.wwf.gr/images/pdfs/wwf-to_avrio_tis_elladas.pdf

[21] Bank of Greece, "The Environmental, Economic and Social Impacts of Climate Change in Greece", June 2011, http://www.bankofgreece.gr/Pages/el/klima/results.aspx

[22] WWF, "Greece faces a 21st century red alert as a result of climate change", 11.12.2012, http://goo.gl/rtRgD

The European energy strategy

Since October 2009 the EU's national leaders have set a target for reducing European greenhouse gases by 80-95% by 2050, compared to 1990 levels, as part of the wider aim of a 50% cut in global emissions by 2050.

In December 2011, the European Commission published the **Energy Roadmap to 2050**[23] where the challenges and strategies for achieving the above target were presented. The report underlines that in order to achieve an 80-95% reduction in European emissions by 2050, a 40% reduction will have to be achieved by 2030. With regards to the European power generation system, the Roadmap notes that it will need to achieve a significant level of decarbonisation by 2030 (57–65% in 2030 and 96–99% in 2050), which means that "*for all fossil fuels, carbon capture and storage will have to be applied from around 2030 onwards in the power sector*".

In all scenarios examined by the Roadmap, the electricity sector in 2050 will have to be practically zero-carbon, while the RES share in electricity production will have reached 64-97%, depending on the contribution of nuclear energy and CCS.

It is interesting that in 2009 the European electricity sector chief executives, who represent over 70% of power generation in the EU, including Greece's PPC, signed a declaration[24] in which they committed to a carbon-neutral power supply in Europe by 2050. In that direction, EURELECTRIC, the European Union of the Electricity Industry, published in 2010 the report **"Power Choices Pathways to Carbon-Neutral Electricity in Europe by 2050"**[25] in which a cost-effective and secure path towards achieving the above target is described.

Although European policies can't be described as ambitious, Europe has managed to be a global leader in the effort to decarbonise the energy system. Particularly in the power sector, the RES share in the EU during 2002-2011 increased by 61% (from 12.7% to 20.4%)[26]. The increase was much higher in countries that adopted ambitious policies for the promotion of RES, such as Germany, where a 173% increase was noted in the RES share (from 7.4% to 20.3%) or Denmark where the increase was 111% (from 18.4% to 38.8%).

The most ambitious energy strategy in the EU is that of Denmark, which has set a goal of covering the entire energy supply by renewable energy in 2050.[27] More specifically, Copenhagen has set a goal of achieving carbon neutrality for all the energy consumed in 2025.[28] In January 2013, the International Energy Agency (IEA) published a report[29] which describes how the Scandinavian countries (Finland, Norway, Sweden Denmark and Iceland) could

[23] European Commission, Energy Roadmap 2050, 15.11.2011 http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm

[24] EURELECTRIC, "A Declaration by European Electricity Sector Chief Executives" http://www.eurelectric.org/CEO/CEODeclaration.asp

[25] EURELECTRIC "Power Choices - Pathways to Carbon-Neutral Electricity in Europe by 2050", 2009 http://www.eurelectric.org/PowerChoices2050

[26] EUROSTAT, Electricity generated from renewable sources - % of gross electricity consumption http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&plugin=1&language=en&pcode=tsdcc330

[27] Danish Ministry of Climate Energy and Buildings, "DK Energy Agreement", March 22 2012 http://www.kemin.dk/Documents/Presse/2012/Energiaftale/FAKTA%20UK%201.pdf

[28] "Copenhagen to become first carbon neutral capital by 2025", 24.05.2012, http://usa.um.dk/en/news/newsdisplaypage/?newsid=b08d4cce-9c7a-44d7-801d-310977fcd2ad

[29] IEA, "First IEA regional technology study plots carbon-neutral Nordic energy system", 22.01.2013, http://www.iea.org/etp/nordic/

achieve a carbon-neutral energy system by 2050. The Finnish government is already aiming to become the first European country to phase out coal use in power by 2025.[30]

At the same time, the United Kingdom is making decisive steps towards decarbonising its power system. According to the proposed legislation for energy submitted to Parliament[31], the emissions of new thermal units should not exceed 450gCO_2/kWh, while all the proposed amendments that have been submitted since then aim to further decrease that limit. In practice, this means that every new coal power unit in the UK will have to operate using CCS technology right from the beginning.

Countries outside Europe have also been preparing for terminating their dependence on coal. In the USA, 143 coal power stations of a total 54GW of power have closed over the past years, and the Sierra Club organisation is campaigning in order to withdraw another 50GW by 2015.[32] The Ontario Region in Canada recently decided to shut down all coal-fired stations operating today, of a total capacity 3GW,.[33] In Los Angeles, the 2nd largest metropolitan area in the United States, it was decided in March 2013 that by 2025 all electricity produced from coal plants - which today covers 39% of electricity demand - will have stopped.[34]

The decentralised RES growth shakes the traditional electricity companies

More and more analysts confirm that there is an ongoing energy revolution, which threatens to turn traditional electricity companies into "*the dinosaurs of our energy system*", as was memorably noted in a special report by Reuters.

In January, the Edison Electric Institute, the association of the United States' shareholder-owned electric power companies, pointed out that the development of decentralised forms of energy production such as Photovoltaics (PV) threatens the viability of traditional power industries, since, in the near future, consumers will be able to produce on their own the energy they consume and thus disconnect from the grid.[35]

Along the same lines, the UBS investment giant in its recent report **"The unsubsidised solar revolution"** noted that the significant reduction in the cost of PV systems, in combination with the rise of power tariffs, means that households might naturally opt for a PV system with battery storage, as early as 2014[36], which would lead to a drastic transformation in the way we perceive energy systems today. The UBS analysts suggest that by 2020, up to 9% of the electricity demand in Germany, Italy and Spain could be covered by the installation of 43GW of autonomous, unsubsidised solar energy systems.

Such a development would have a major impact on traditional power industries. UBS estimates that there would be a drop in the capacity of Germany's lignite stations from 72% to 59% and coal stations would drop from 47% to 31%. As a result, the report suggests that electricity companies will

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30 http://www.bloomberg.com/news/2012-09-28/finland-may-phase-out-coal-use-in-power-by-2025-minister-says.html
31 Energy Bill, 29.11.2012, http://www.publications.parliament.uk/pa/bills/cbill/2012-2013/0100/130100.pdf
32 Sierra Club, Beyond Coal campaign – Victories http://content.sierraclub.org/coal/victories
33 Reuters, "Ontario to add renewable energy, shut coal-fired power plants", 01.03.2013 http://www.reuters.com/article/2013/03/01/utilities-ontario-ieso-idUSL1N0BT5TX20130301
34 Bloomberg, "Los Angeles Halts Using Electricity From Coal Plants", 20.03.2013 http://www.bloomberg.com/news/2013-03-19/los-angeles-halts-using-electricity-from-coal-plants.html
35 Edison Electric Institute, "Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business", 01.2013 http://www.eei.org/ourissues/finance/Documents/disruptivechallenges.pdf
36 Renew Economy, "UBS: Boom in unsubsidised solar PV flags energy revolution", 23.01.2013, http://reneweconomy.com.au/2013/ubs-boom-in-unsubsidised-solar-pv-flags-energy-revolution-60218

have to shut down 40% of the existing coal and natural gas-fired power units in order to increase their profit margin.[37]

In a recent study, the German Institute for Economic Research (DIW) estimated that a lignite unit of 1.1GW that becomes operational in 2015 will have total losses of €426 million during its 40-year lifespan.[38]

Finally, it is worth mentioning that, over the past years, investments in coal stations in Germany have frozen, despite the insignificant CO_2 prices and the high natural gas prices, as the figures in Table 1 show. [39]

Table 1: Development of investments in coal stations in Germany

	Number of stations	Total power (MW)
Announcements for the construction of coal units in 2007	39	3.000
In operation	2	2.900
Under construction	8	8.600
In planning process	3	2.700
Put on hold	6	5.400
Abandoned	20	19.400

The external cost of coal

It is widely believed that burning fossil fuels – especially lignite, the cheapest fuel by Greek standards – is the most economical option for electricity production. However, such a view takes into account only the market price of the fuel, in other words the expense borne by the electricity producer.

In reality, alongside the production of useful energy, the burning of fossil fuels has a number of negative impacts on the environment and on public health, the costs of which are borne by people, either in the surrounding region or somewhere else. The same applies, of course, to the impacts of fuel extraction and transport. This economic cost is nonetheless "hidden", as it is not included in the production cost and, therefore, burdens society rather than the producer, providing it with an economic benefit and competitive advantage.

A number of studies have attempted to quantify these "externalities" and have concluded that, if the impacts of extraction and burning were included in the power generation cost of fossil fuels, any economic advantage would disappear.

The European Environment Agency (EEA) published in November 2011 the report **"Revealing the costs of air pollution from industrial facilities in Europe"**,[40] which analyses 622 of the largest polluting facilities in Europe, including the 7 lignite stations belonging to the PPC.[41]

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[37] Renew Economy, "The beginning of the end for centralised generation?", 14.03.2013, http://reneweconomy.com.au/2013/the-beginning-of-the-end-for-centralised-generation-84641

[38] Deutsches Institut für Wirtschaftsforschung, Berlin, "Bedeutung der Braunkohle sinkt: Neue Kraftwerke und Tagebaue sind überflüssig", 28.11.2012 http://www.diw.de/de/diw_01.c.412066.de/themen_nachrichten/bedeutung_der_braunkohle_sinkt_neue_kraftwerke_und_tagebaue_sind_ueberfluessig.html _tagebaue_sind_ueberfluessig.html

[39] Deutsche Umwelthilfe, "Projects of coal-fired power plants in Germany since 2007", 11.2012 http://www.duh.de/uploads/media/New_coal_plants_Germany_2012_DUH.pdf

[40] EEA, "Revealing the costs of air pollution from industrial facilities in Europe", 24.11.2012 http://www.eea.europa.eu/pressroom/newsreleases/industrial-air-pollution-cost-europe

[41] The report uses publicly-available data from the European Pollutant Release and Transfer Register (E-PRTR) regarding nearly 10 000 individual facilities in Europe in 2009. The analysis builds on existing policy tools and

According to the data, given in Table 2, the external cost resulting from the operation of lignite stations in 2009 ranged between €2.33 and €3.91 billion, depending on the range of estimated damage costs for the value of a statistical life (VSL) and value of life year (VOLY).

Table 2: The external cost resulting from the emissions of lignite plants in Greece

	Reported emissions (tonnes)				Total damage cost (million €)	
Lignite Plant	CO_2	NO_x	SO_x	PM_{10}	Low 'VOLY'	High 'VSL'
Megalopoli A	4.460.000	3.090	184.000	5.590	692	1.609
Agios Dimitrios	12.900.000	24.800	58.000	471	629	944
Kardia	9.650.000	17.400	9.280	3.520	393	503
Ptolemaida	5.030.000	6.260	6.670	5.050	225	320
Amyntaio	4.400.000	4.270	20.200	1.230	216	330
Megalopoli B	2.910.000	2.220	1.260	59,2	105	115
Meliti	1.880.000	1.420	2.240	N.R.	71	84
Total					2.332	3.906

It should be noted that:

- The calculated pollution cost does not include the cost of lignite mining and transportation
- The cost taken here for CO_2 emissions is EUR 33.6 per tonne, based on a methodology developed by the UK government for carbon valuation in public policy appraisal. For 2030, the methodology recommends an increased value of EUR 85.7 per tonne
- The cost of other pollutants (excluding CO_2) is 35.5-59.4% of the total
- Since the time of the study (2009), three of the oldest and most polluting lignite units have been shut down (two out of the three Megalopoli-A units and the first out of four Ptolemaida units).
- As a comparison, in 2009 the total PPC income from energy sales was €5.5 billion.[42]
- By taking into account the fact that in 2009 the PPC's lignite units produced 30.5 million MWh,[43] the €2.33-3.91 billion range of the total external cost corresponds to a surcharge range of production cost of 76,3-127,9 €/MWh

More recently, on 7th March 2013, the Health and Environment Alliance (HEAL), a non-profit organisation of 70 members, published the report **"Coal's unpaid health bill"**.[44] It provides a review of scientific data regarding the health impacts of atmospheric pollution, as well as an economic estimate of the health costs associated with atmospheric pollution caused by Europe's coal stations.

From the report it appears that the cost associated with the operation of lignite stations in Greece in 2009 ranges from €1.47 to 4.09 billion, depending on the two mortality-rate estimation scenarios examined by the report, based either on the value of life year (VOLY) or

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methods, such as the methods developed under the EU's Clean Air for Europe (CAFE) programme to calculate a range of estimated damage costs arising from air pollutants. The pollutants examined are regional air pollutants (NH3, NOx, PM10, SO2, volatile organic compounds (NMVOCs)), heavy metals (arsenic, cadmium, chromium, lead, mercury and nickel), organic micropollutants (benzene, polycyclic aromatic hydrocarbons (PAHs) and dioxins & furans), and CO_2.

42 PPC, 2009 Annual Report http://www.dei.gr/Documents/DEH%20Deltio%202009%20GR%20gray.pdf

43 IPTO, Monthly Bulletin of Electric Energy Balance in the Interconnected System, December 2009 http://www.admie.gr/fileadmin/user_upload/Files/energy/energy200912_GR.pdf

44 Health and Environment Alliance, "Coal's unpaid health bill", 07.03.2013 http://www.env-health.org/unpaidhealthbill

on the value of a statistical life (VSL), respectively. Adjusting this cost to the electricity production of Greece's lignite plants in 2009, the range of hidden production cost is calculated at 48.1-133.9 €/MWh.

Of particular interest is also a study conducted by Harvard's Medical School researchers, published in the Annals of the New York Academy of Sciences in 2011.45 The study provides a detailed review and a cost estimate of the health, economic and environmental impacts associated with each stage in the life cycle of coal (extraction, transport, processing, and combustion). It concludes that if the external cost was included in the production cost of coal-fired electricity production, the latter would have a 93.6-268.9 $/MWh increase. The researchers also point out that these figures are an underestimation of the total external cost, since the impacts of toxic substances, heavy metals and aquatic eutrophication on ecosystems have been omitted, while a great deal of uncertainty exists about the real impacts of a destabilised global climate.

Finally, in a recent report the International Monetary Fund (IMF) estimated that in 2011, governments around the world provided $480 billion of subsidies for fossil fuel consumption, while the lack of taxes on the excluded external costs were equivalent to $1.4 trillion of indirect subsidies, assuming an illustrative value for global warming damages of $25 per ton of CO2 emissions. The IMF underlines that removing these subsidies alone could lead to a 13% decline in CO2 emissions worldwide.46

The European Union Emission Trading Scheme

The EU emissions trading system (EU ETS) is a cornerstone of the European Union's policy to combat climate change and also the biggest international system for trading greenhouse gas emission allowances. The first ETS trading period lasted from 2005 to 2007, the second trading period expired only recently (2008-2012), and we are currently in the third period which spans until 2020. The EU ETS covers more than 11,000 power stations and industrial plants, which represent around 40% of the total greenhouse gas emissions from all EU countries.

The existing EU Directive[47] and national legislation[48] dictate that since 01.01.2013 all electricity plants in Greece exceeding 20MW are obliged to buy and sell emissions allowances according to their certified CO_2 emissions. On the contrary, some industrial sectors, particularly the energy-intensive ones, will benefit from a free allocation of permits that will decrease annually, on the basis of harmonised rules regarding international competition.

According to analysts and the European Commission itself, the EU ETS is facing an oversupply of allowances. This is mainly due to the reduced economic activity following the European recession, the extensive use of the international carbon credits provided by Kyoto's Flexible mechanisms (which covered 13% of the total emissions in 2011) and the important expansion and development of renewables. In its recent study regarding "The state of the European carbon market in 2012"[49] the European Commission concluded that by early 2012, a surplus of 955 million allowances had been accumulated. Even if the part of the surplus arising from the use of international credits for compliance was excluded, the surplus would still have been 406 million allowances. In comparison, the annual emissions average in the EU ETS for 2008-2012 was €1.86 billion.

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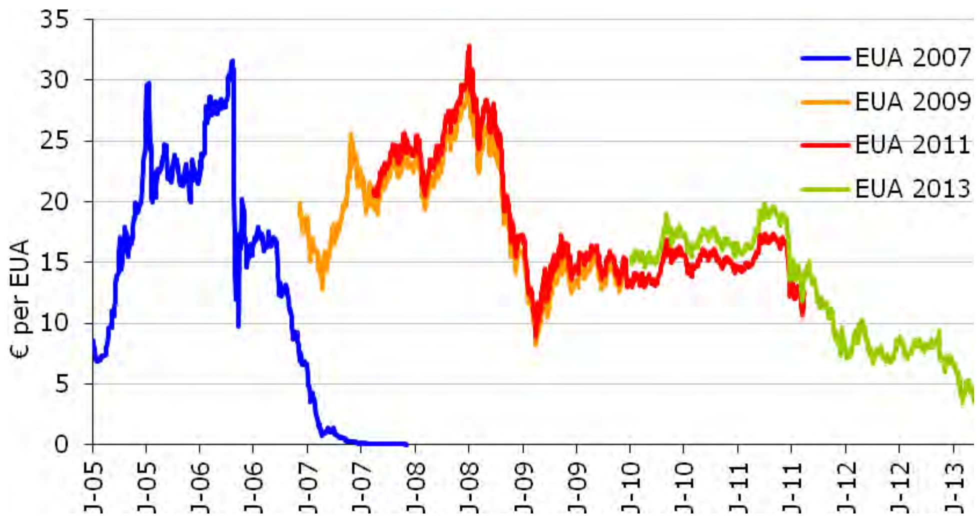
[45] P. Epstein et al, "Full cost accounting for the life cycle of coal"
http://solar.gwu.edu/index_files/Resources_files/epstein_full%20cost%20of%20coal.pdf
[46] Energy Subsidy Reform: Lessons and Implications, IMF 2013
http://www.imf.org/external/np/pp/eng/2013/012813.pdf
[47] EU Directive 2009/29/EC revising EU Directive 2003/87/EC
[48] Revision of 54409/2632/2004 Joint Ministerial Decision, 2030/29.12.2010 Official Government Gazette
[49] European Commission, The state of the European carbon market in 2012, 14.11.2012
http://ec.europa.eu/clima/policies/ets/reform/docs/com_2012_652_en.pdf

This oversupply resulted in a drastic reduction in the emissions' price in 2012, as can be seen in Figure 1, and a consequent undermining of the EU ETS' aim and operation. To deal with this problem, the European Commission suggested revising the EU Directive 2009/29/EC, in order to change the timing of the auctioning in phase 3, and postpone auctions planned for the first years of the phase, to the last (backloading proposal), without excluding the adoption of structural changes, such as raising the emissions reduction target set for 2020, withdrawing some phase 3 allowances on a permanent basis, extending the scope of the EU ETS to other sectors et al.

Figure 1: Development of EUAs emissions rights prices (January 2005 – April 2013)



The emissions rights cost for the thermal power generation units is included in their variable production cost. According to 643/2011 of RAE (Greece's Regulatory Authority for Energy), the inclusion of the CO_2 emissions cost in the monthly generators' offers is calculated by adding up the average share prices of a future December 2013 discharge of the previous month.

Regardless of what will happen during the ongoing trading period expiring in 2020, the EU's carbon emissions reductions targets up to 2050 are essentially linked, and practically coincide, with a parallel increase of the emissions costs per tonne CO_2.

The trajectory projections of the emissions rights costs are presented in Table 3, according to the scenarios developed by the European Commission (taken from the Energy Roadmap to 2050), EURELECTRIC (taken from the Power Choices report) and the working group of the Bank of Greece (from the report on the economics of climate change):

Table 3: Projected price trajectory of CO_2 emissions rights

€ /t CO2	2020	2030	2050
European Commission - Diversified supply technologies scenario	25	52	265
European Commission - High energy efficiency scenario	15	25	234
European Commission – High renewable energy sources (RES) scenario	25	35	285
European Commission – Delayed CCS scenario	25	55	270
European Commission – Low nuclear scenario	20	63	310
EURELECTRIC - Power Choices	25	52	103
Bank of Greece – Mitigation scenario	25	60	190

THE DEVELOPMENT OF THE GREEK POWER SYSTEM

This chapter provides an overview of the Greek power sector and the published scenarios regarding its future development, aiming mainly to analyse the tendencies and estimate the figures necessary for the economic analysis of the lignite units that follows.

The current situation

The development of end-use electricity consumption in Greece over the past decade, according to EUROSTAT statistics, is represented in Chart 1. The electricity consumption increased constantly until 2008, when it started to decline as a result of the recession. This was especially apparent in the transport and agricultural sector (the decrease in energy consumption during 2008-2010 was 12.3% and 7.4% respectively), while the industrial and household sectors were affected to a lesser extent (decrease by 4.4%). Chart 2 shows the changes in the distribution of electricity consumption per sector between 2000 and 2010, with a noticeable reduction in the industry sector.

Chart 1: End-use electricity consumption per sector (EUROSTAT)

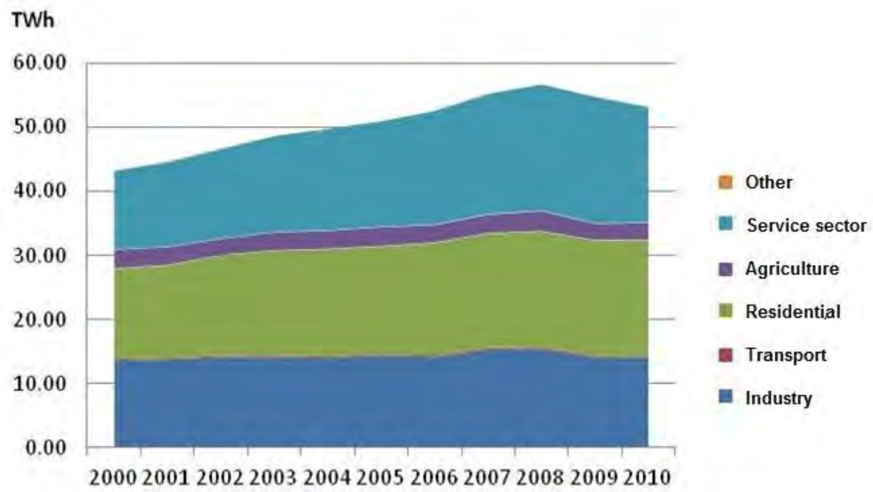
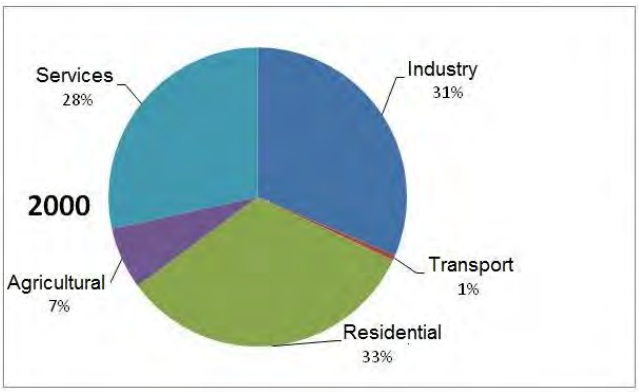
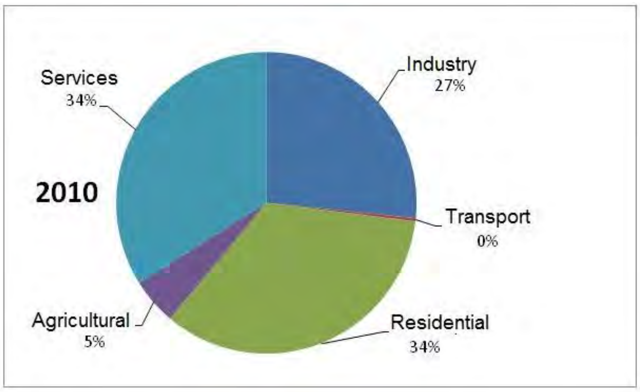


Chart 2: Electricity consumption distribution per sector in 2000 and 2010 (EUROSTAT)





Installed capacity and electricity generation per fuel are presented in Charts 3 and 4, respectively, while Chart 5 shows the distribution of production per fuel between 2000 and 2010. The share of RES (including large hydro) and natural gas have increased significantly at the expense of lignite and oil. The increase in the RES quota is largely due to the increase in the installed production of wind farms over the past decade, as is illustrated in Chart 6. It should be noted that, according to LAGIE (the Operator of the Electricity Market in Greece), there have been 1704 MW of RES installed between 2010 and the end of 2012, of which 427 MW is wind and 1260 MW is photovoltaic energy.

Chart 3: Installed capacity (EUROSTAT)

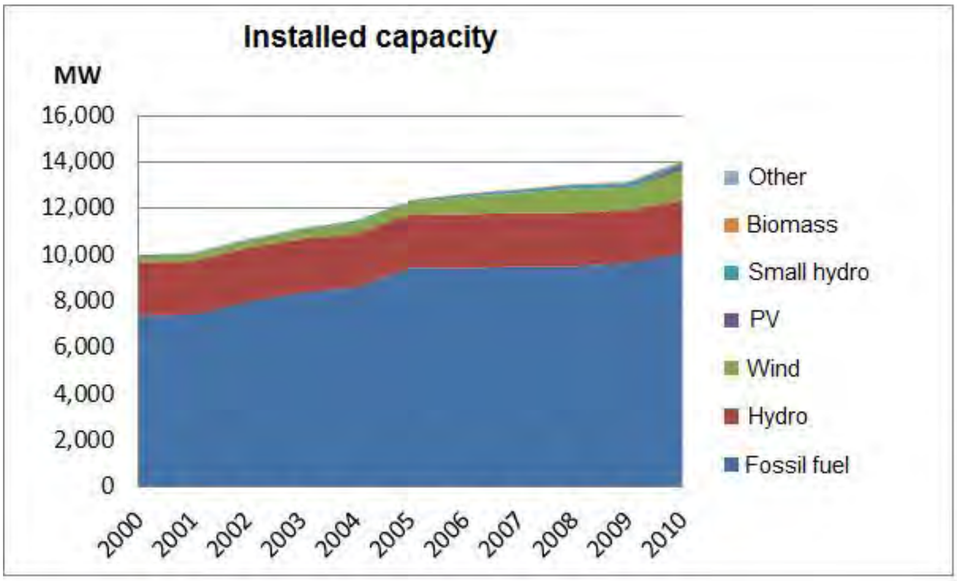


Chart 4: Electricity generation per fuel (EUROSTAT)

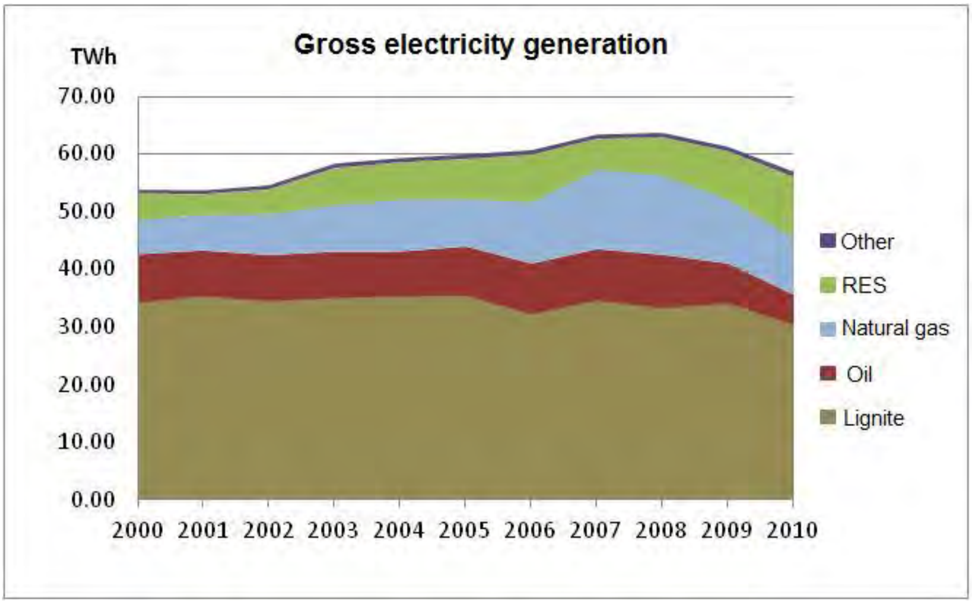
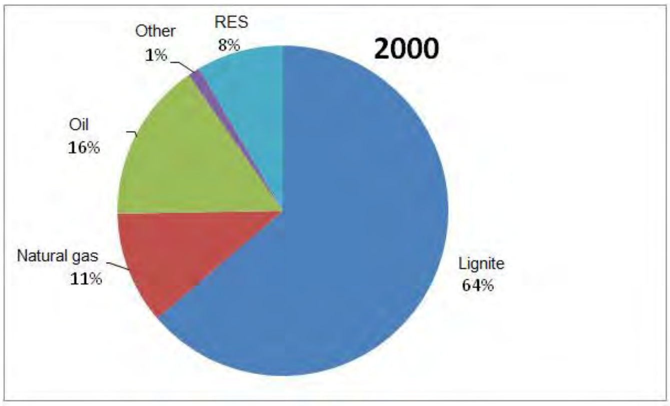


Chart 5: Electricity generation per fuel for 2000 and 2010 (EUROSTAT)



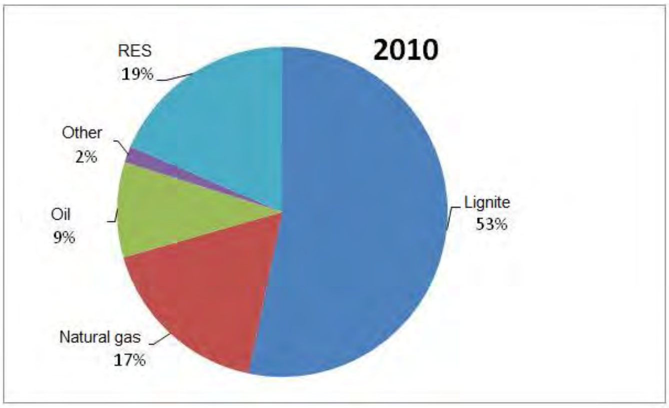
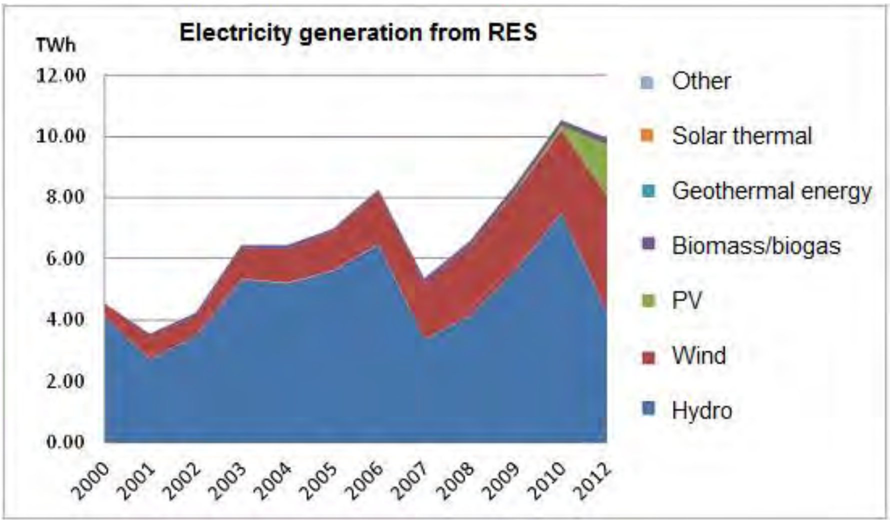


Chart 6: Electricity generation from RES (based on EUROSTAT and LAGIE[50] data)



Future Development

With respect to the future development of the power system in Greece, the latest MEECC (Ministry of Environment, Energy and Climate Change) report on the long-term development of the system, entitled "Energy Roadmap to 2050" (March 2012) was analysed. The report examines the 2020-2050 period, using the National Renewable Energy Action Plan (NREAP) as a starting point. The NREAP presents the development plan for the national energy system, with the aim of achieving the obligatory targets set by Directive 2009/28/EC and by law 3851/2010 of the Greek Parliament.

The penetration of RES in the energy system according to the NREAP is presented in Chart 7, along with the 2020 targets: 20% of the gross end-use energy consumption for heating and cooling, 40% of the electricity consumption and 10% of the energy used in transport. In Chart 8, the development of installed capacity and electricity generation per fuel are presented.

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[50] Monthly Bulletin RES Dec 2012 and Monthly Bulletin of DAS (Daily Ahead Scheduling) Transactions System Dec 2012

These charts demonstrate that the main factor in achieving the national targets by 2020 is the reduction of the electricity produced by lignite power stations. Lignite-fired installed capacity is expected to drop to a total of 3,250 MW, while natural gas power production will rise to 5,130 MW. The total RES power in 2020 is expected to rise to 13,271 MW, consisting mainly of wind farms (7,500 MW) and hydroelectric (HEP) stations (4,530 MW, including pumping units), followed by PVs (2,200 MW), biomass and solar-thermal (250 MW) and geothermal (120 MW) units.

Chart 7: RES penetration according to the National Renewable Energy Action Plan (NREAP) (Greek Energy Roadmap to 2050)

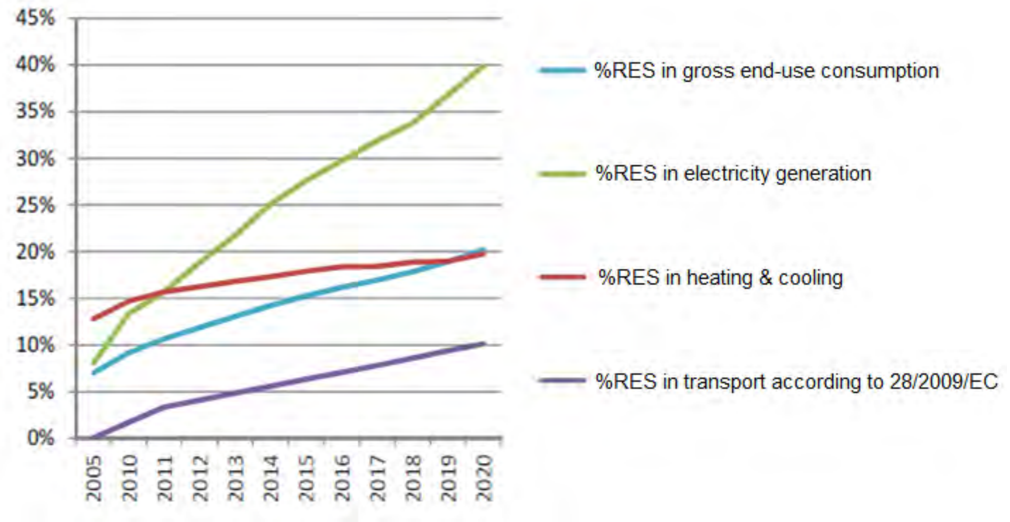
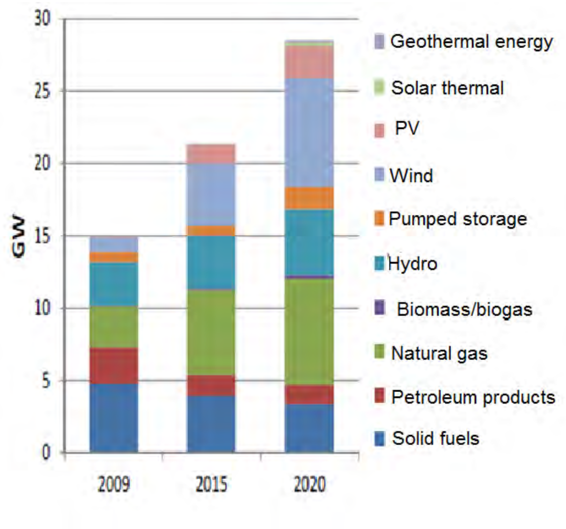
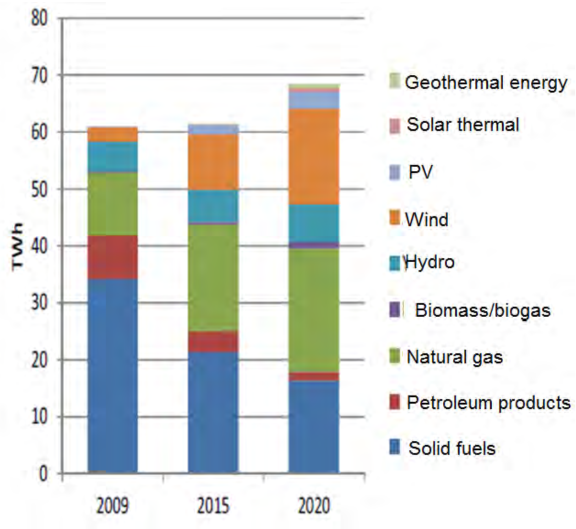


Chart 8: Development of installed capacity and electricity generation per fuel according to the National Renewable Energy Action Plan (NREAP) (Greek Energy Roadmap to 2050)





It should be noted that the construction of the two new lignite units Ptolemaida-5 and Meliti-2 has been included in the NREAP, while the penetration of RES is somewhat under-estimated. According to the latest LAGIE figures at the time of the study[51], the installed operating capacity

[51] LAGIE, Renewable energy sources and CHP Monthly Bulletin, Feb. 2013

of PV stations in mid-February 2013 was 1,838 MW (1,404 MW in the Interconnected System), projected to exceed the 2020 target by the end of 2014, reaching 2,265 MW.

Regarding the development of the system beyond 2020, the Energy Roadmap takes into account the recession, assuming that the economy will return to a 2.7% growth by 2015. The study examines three main scenarios: the "Business As Usual" (BAU) scenario, which assumes a conservative implementation of environmental and energy policies, the "Maximization of RES" (MRES) scenario and the "Minimum Cost of Environmental Policies" (MCEP) scenario, while there are also two alternatives to the MRES and MCEP scenarios, assuming a total CO_2 reduction of 60% and 70% by 2050, compared to 2005 levels.

The development of total electricity demand in the five scenarios is given in Chart 9. The demand reaches approximately 70TWh in the Reference scenario, compared to 80-85 TWh in the other scenarios. This is due to the intense electrification of the energy system and, most importantly, to the increase of electrification in transport.

The RES penetration in the three scenarios and their alternatives is shown in Chart 10. The RES share in the gross final demand ranges from ~45% to ~70%, while in electricity generation the share ranges from ~75% in the BAU scenario to ~95% in the MRES scenario.

Chart 9: Final electricity demand (Source: Greek Energy Roadmap, MEECC)

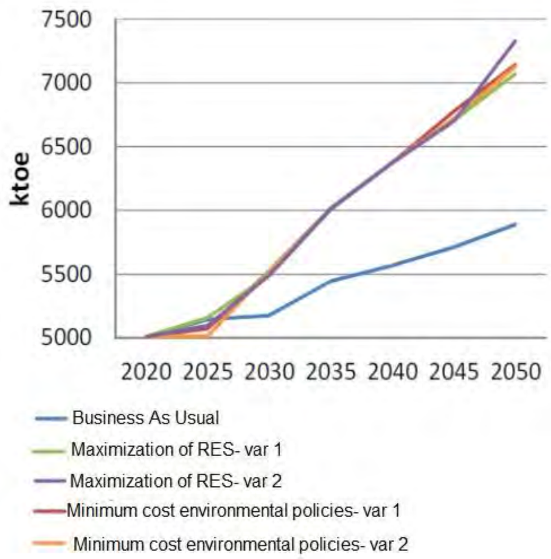
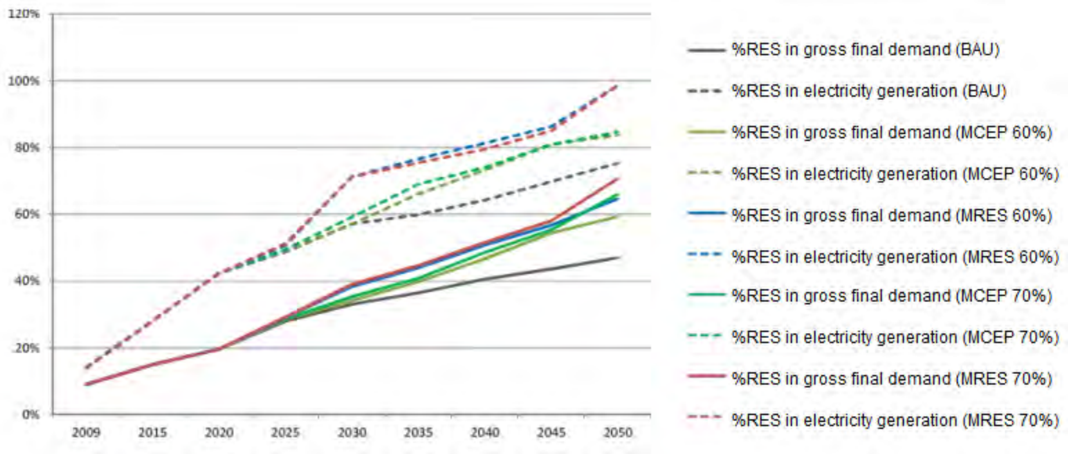


Chart 10: RES penetration for the basic scenarios and their variations (Greek Energy Roadmap to 2050)



Electricity production and the development of installed capacity per fuel are depicted in Charts 11 and 12, respectively. The lignite-fired energy production in the BAU scenario doesn't exceed 13%, while it is practically zero in the MRES and MCEP scenarios. Even in the MCEP-a scenario, where increased energy imports are assumed, the production of lignite remains at a 6% level, including though the use of Carbon Capturing and Storage (CCS) technology. A similar reduction occurs for natural gas-fired electricity production, which ranges between 10-16% in the MCEP scenarios and remains below 1% in the MRES scenarios. It should be noted that it is assumed that the island interconnection will be completed by the end of 2030 and, therefore, there will be no oil-fired electricity production.

Chart 11: Electricity production per fuel for each scenario (Greek Energy Roadmap to 2050)

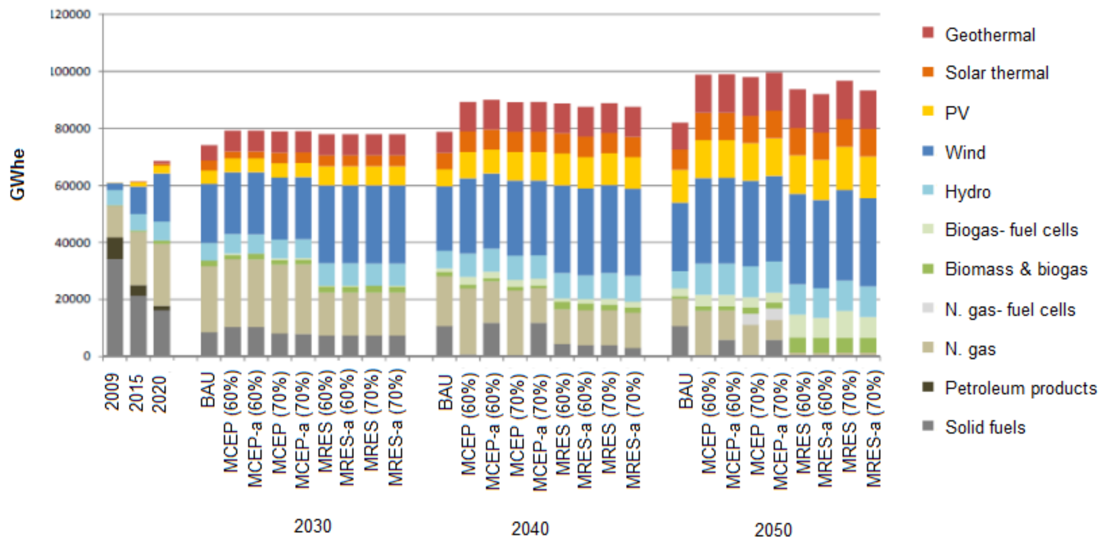
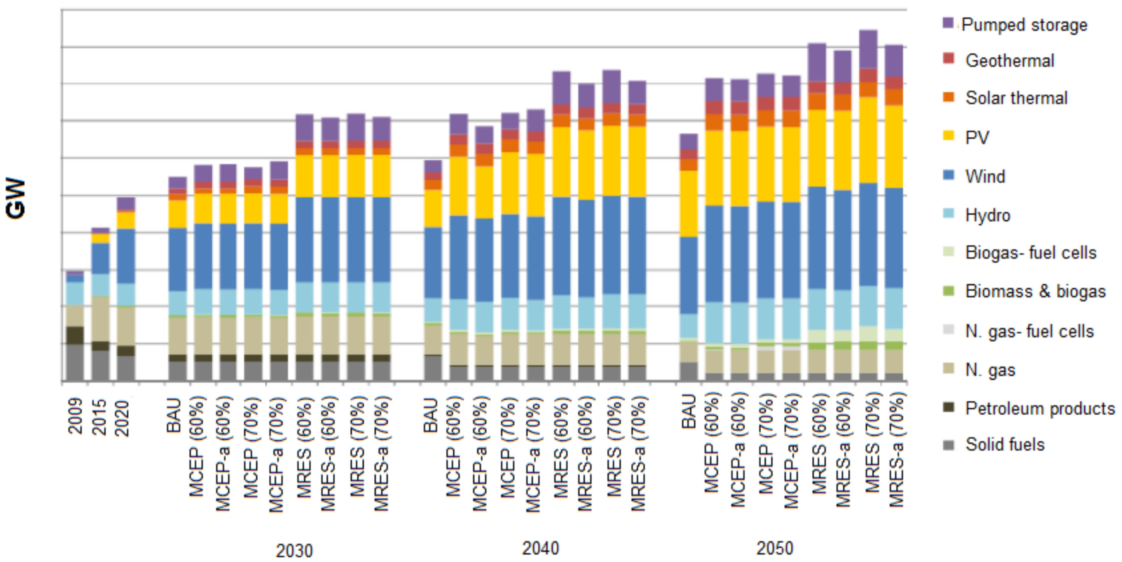


Chart 12: Development of installed capacity per fuel for each scenario (Energy Roadmap to 2050)



ECONOMIC ANALYSIS OF THE LIGNITE UNITS

In this chapter, the results of a sustainability analysis of the Ptolemaida-5 and Meliti-22 lignite units are presented, according to the methodology described in Appendix A. The main goal of this analysis is to investigate the operation of the units, taking into account the possible future developments in the structure and operation of the electricity system.

The analysis assumes that both units will become operational in 2020 and that they will be of similar technology (supercritical fluidized bed units) and with the same technical characteristics. The analysis goes up to 2050, assuming that the economic lifespan of the units is 30 years. In the attempt to include dynamic characteristics such as demand fluctuations, incremental increases of RES share etc., the operation of the units was examined using 10-year timeframes, i.e. for 2020, 2030, 2040 and 2050. Four scenarios of operation were considered, based on particular assumptions for the development of the system. The main assumptions for the scenarios used are summarized in Table 4, followed by the main assumptions of the study and the results of the analysis.

Table 4: Main assumptions per scenario[52]

Scenario	Assumptions
Scenario 1	Power demand and RES share, as in BAU scenario of Greek Energy Roadmap to 2050. CO_2 emissions prices as "alternative scenario" (see table 2). No CCS retrofit takes place.
Scenario 2	Power demand and RES share, as in "Maximization of RES" scenario of Greek Energy Roadmap to 2050. CO_2 emissions prices as in the EC's Energy Roadmap (see table 2). No CCS retrofit takes place.
Scenario 3	Energy demand and RES penetration, as in "Maximization of RES" scenario of Greek Energy Roadmap to 2050. CO_2 emissions prices as in the EC's Energy Roadmap (see table 4). Both lignite units are retrofit to CCS in 2030.
Scenario 4	Energy demand and RES penetration, as in "Minimum Cost of Environmental Policies" scenario of Greek Energy Roadmap to 2050. CO_2 emissions prices as in EC's Energy Roadmap (see table 4). Both lignite units are retrofit to CCS in 2030.

Study Assumptions

- **Demand development**

For the purposes of the study, it was assumed that the development of electricity demand is along the lines of the three basic scenarios of the Greek "Energy Roadmap to 2050" (as noted in Chart 9). More specifically, for scenario 1 the BAU figures were used, for scenarios 2 and 3 the MRES-60% figures and for scenario 4 the MCEP-60% demand. The demand levels are presented in Chart 13.

It should be noted that for all scenarios a complete island interconnection beyond 2030 was assumed, as is described in the Energy Roadmap to 2050. For 2020, only the Cyclades Islands are considered to be interconnected, as is reported in the Ten Year Network Development Plan 2014-2023 (TYNDP) of the Independent Power Transmission Operator of Greece (IPTO).[53]

[52] It is worth emphasizing that the Business As Usual (BAU) scenario of the MEECC (examined in scenario 1) leads to a 40% emissions reductions by 2050. These emissions reductions (60% in the three other scenarios), concern the emissions of the energy system, hence the emissions from agriculture or changes of land use or waste products are not included.

[53] IPTO, Ten Year Network Development Plan 2014-2023, Dec 2012

Using the Regulatory Authority for Energy (RAE) data for the consumption of the Non-Interconnected Islands for 2008[54] and assuming the same growth rate as that of the mainland for consumption during 2010-2020, the energy demand of the islands was calculated, excluding that of the Cyclades, which was deducted from the total demand. The balance of trade was taken as zero, without any further analysis.

The losses of the distribution network between 2000-2010 are given in Chart 14. Regarding future losses, it was assumed that they will rise to 6% by 2020 and then drop linearly to 4% by 2050.

Chart 13: Electricity demand for the different scenarios

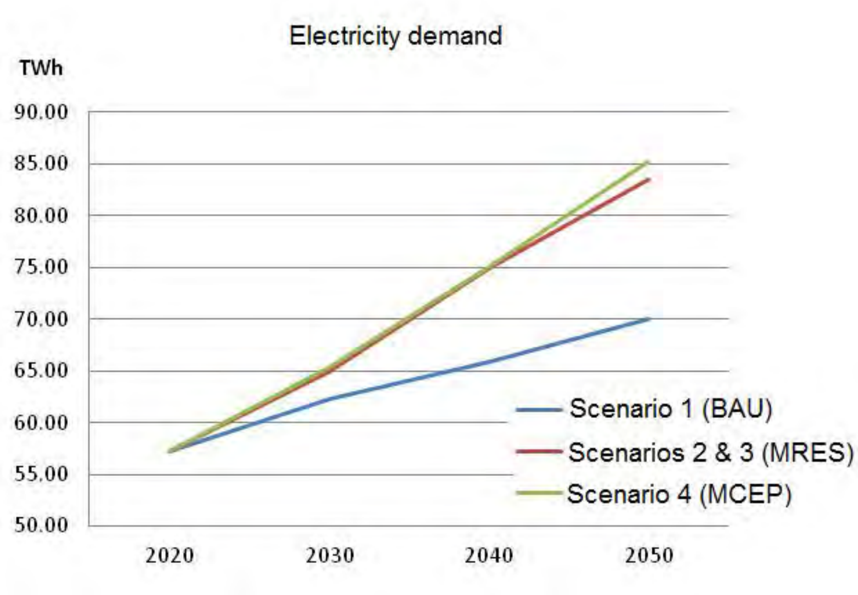
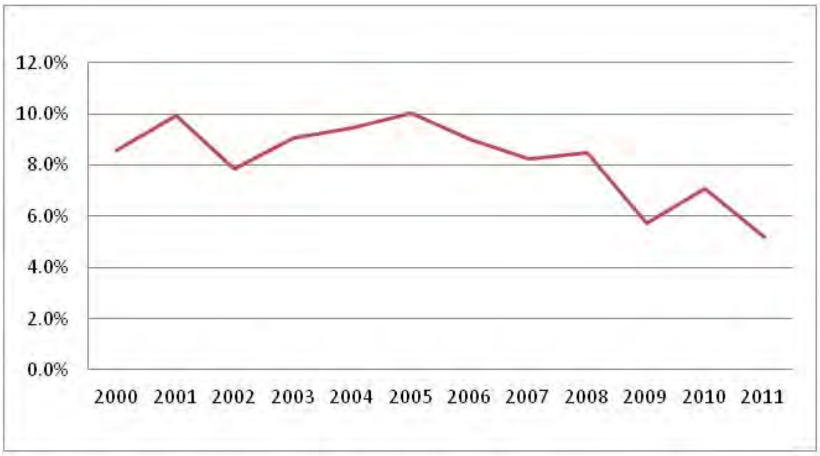


Chart 14: Distribution losses (EUROSTAT)



[54] RAE, Energy Demand and Production in Non-Interconnected Islands Annual Report 2008

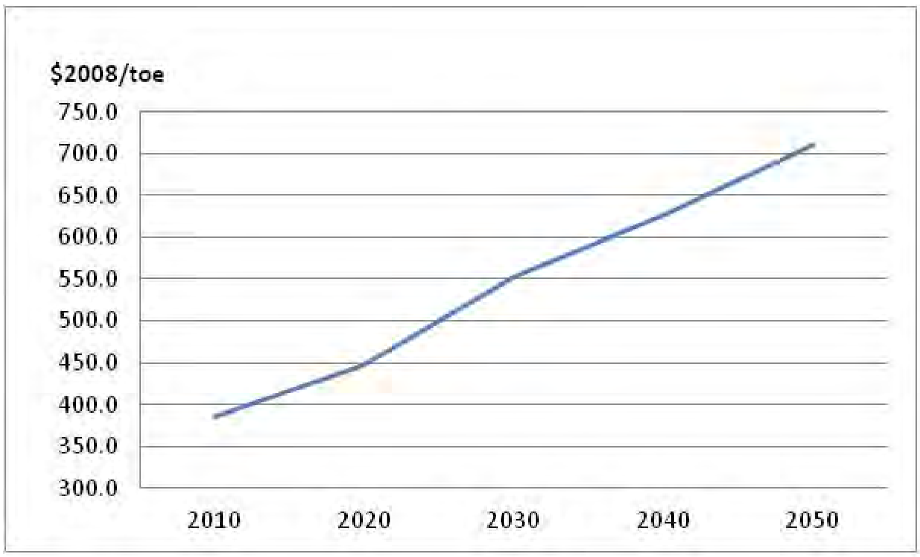
- **Fuel cost**

The cost of lignite mining is an important cost factor; however, finding relevant explicit data proved difficult. A PPC study regarding the exploitation of Ptolemaida's lignite reserves[55] refers to an excavation operating cost of 12€/t, while a Mines Management report[56] estimates 16€/t for Ptolemaida and 19€/t for Florina. It was decided to use the latter figures in the current study, and to consider them as constant throughout the economic evaluation period. Assuming a heating power of 1,300kcal/kg for the Ptolemaida reserve and 1,800kcal/kg for the Florina reserve (current estimates for the Florina PPC reserve range between 1,785kcal/kgr and 1,888kcal/kgr),[57] results in fuel costs for both units coming down to 12.3€/Gcal and 10.6€/Gcal, respectively.

As for natural gas, the cost trajectory provided in the reference scenario of the EU Energy Roadmap to 2050[58] was used, given in Chart 15.

The use of hard coal, oil or other alternative fuels was not examined in the current study, and lignite and natural gas costs remained the same for all scenarios examined. Moreover, other taxes or charges were not taken into account, such as the special levy for lignite, since, on the one hand, there cannot be an estimate for their range during the period examined, and, on the other hand, the aim was to base the analysis on estimates of the actual fuel cost.

Chart 15: Price fluctuation for natural gas (Energy Roadmap 2050, EC)



- **Impact of RES**

In order to assess the development of RES in relation to both the installed capacity and the type of technology used, the results from the BAU, MRES-60% and MCP-60% scenarios of the Greek Energy Roadmap to 2050 were used (see Chart 12). The "Other RES" category was omitted. In all scenarios, priority was given to the absorption of the electric energy produced by Renewable Energy Sources (RES) (excluding large hydroelectric and pumping units). The

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55 PPC Study and Development Division, PPC's Ptolemaida Lignite Units Exploitation Updated Technical Study, July 2010

56 Leandros M. PPC SA Mines Design and Performance Management, "PPC Lignite Mines – National energy safety factor and economic development derivative in West Macedonia – Perspectives", 2010

57 Kolovos H., Lignite-Energy-Environment The role of lignite in the energy balance of the country, Oct. 2010

58 SEC(2011) 1565 final, Energy Roadmap to 2050 – Impact Assessment and scenario analysis, Dec 2011

electricity produced by RES and its hourly distribution were calculated using the methodology provided in Appendix A.

- **Emissions factors and CO2 emissions allowances costs**

The emissions coefficient applied to the Ptolemaida unit was 961 tCO_2/MWhe, which agrees with the figure provided in a PPC study on carbon capture and storage technology applications.[59] For the Meliti unit, the coefficient was calculated using comparative data from a study conducted for RAE by the RWE Group, regarding the sustainability of supercritical lignite stations.[60] It was estimated to be quite smaller at 858 tCO_2/MWhe, due to the superior quality of the fuel. It should be noted that a supercritical fluidized bed unit technology with the same characteristics was assumed to be used in both units.

The CO_2 emissions allowances cost trend was assumed to follow the reference scenario costs of the EC Energy Roadmap to 2050[61] which were also used in the Greek Roadmap study. Attention should be drawn, however, to the fact that, in the EC Roadmap, the European Commission makes it clear that the reference scenario in practice means abandoning the existing EU climate commitments: "While the reference case development leads to only 40% less GHG emissions from 1990, more than twice as much might be needed, i.e. minus 80-95% by developed economies".

The "decarbonisation" scenarios of the electricity system, compatible with the EU climate commitments presented in the EC Energy Roadmap to 2050, correspond to CO_2 prices being €35-138 higher compared to the reference scenario prices in 2040 and €184-260 compared to 2050 prices. At the same time, the EURELECTRIC "Power Choices" Report predicts CO_2 prices €53 higher compared to the EU reference scenario. Despite the fact that, for the sake of data consistency, only the MEECC figures have been used in the current study, it is unquestionable that, with allowance market prices such as the ones given in Table 3, the economic outcome of the planned lignite units would be considerably worse.

For scenario 1 in particular, by taking into account the latest allowance prices, even lower prices were used, assuming that the prices will increase gradually from 20 €/tCO_2 to 35 €/tCO_2. The progression of the allowance prices that was used is presented in Table 4.

Table 4. CO_2 allowances price progression

€/tCO_2	2020	2030	2040	2050	Scenarios
EC's Energy Roadmap	20	40	52	50	2,3,4
Alternative development	20	25	30	35	1

- **Carbon capture and storage**

Carbon capture and storage technology was examined only in scenarios 3 and 4. The cost development of the technology was taken from the IEA database.[62] It should be noted that the installation cost provided by the IEA refers to new units. In the current study, the system cost was estimated using the cost difference between the IEA units and equivalent units lacking the CCS technology. Additionally, since it is a conversion of an existing unit, the cost increases by 30%, as cited in the PPC Techno-Economic study. These figures are presented in Table 5.

[59] PPC Study-Construction Division of HEP projects , Techno-Economic Report of CO_2 Capture-Transport and Storage for the new Ptolemaida-5 lignite 660 MWe gross power unit, Nov 2011
[60] RWE, Technico-Economic Analysis of Supercritical PF Plant Suitable for Greek Lignite, 2006
[61] SEC(2011) 1565 final, Energy Roadmap to 2050 – Impact Assessment and scenario analysis, Dec. 2011
[62] OECD/IEA, Energy Technology Perspectives 2010, 2010

Carbon transport and storage expenses are also included in the operational cost of the units. For their calculation, figures from the Ptolemaida-5 CCS study were used, where the storage cost for using a ground pipe in the West Thessaloniki region is given as 1.06 €/tCO_2. This figure has been used in the current study for both units, although actual figures will definitely be different, since the cost is directly dependent on the distance between the unit and the CO_2 storage point. Attention should be drawn to the fact that the transport cost to a storage area outside Greece using ships is estimated at 21.92 €/tCO_2, which would certainly have a negative effect on the viability of the units. Finally, the CO_2 capture percentage was assumed at 90%.

Table 5: Techno-economic data for the conversion of the units to CCS (Based on IEA data)

SPC-CSS technology[63]	2020	2030	2040	2050
Capital cost €/kW	751	686	620	554
Operational cost €/kW	65	60	56	51
Rate of return %	34%	34%	35%	36%

Results

Based on the methodology described in Appendix A, the load duration curves were calculated[64] as well as the residual load duration curves that the thermal units are required to meet in 2020, 2030, 2040 and 2050. These curves are presented for each scenario in Charts 16, 17 and 18. It should be noted that scenarios 2 and 3 have the same residual load, since they only differ in the lignite unit conversion to CCS. The diagrams highlight the important consequences of the extensive RES impact especially for years 2040 and 2050, where zero loads occur for several hours, as a result of RES power generation exceeding the demand.

[63] Supercritical pulverized lignite station with CCS
[64] The duration curve is essentially the power distribution in hours, It shows, in other words, the duration of demand for a certain power level

Chart 16: Residual load curves for scenario 1

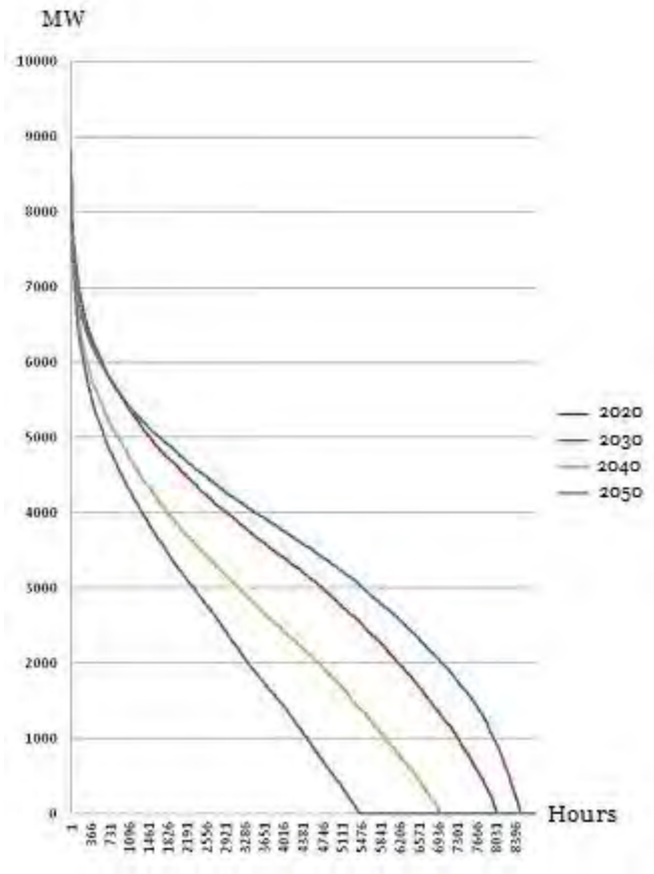


Chart 17: Residual load curves for scenarios 2 and 3

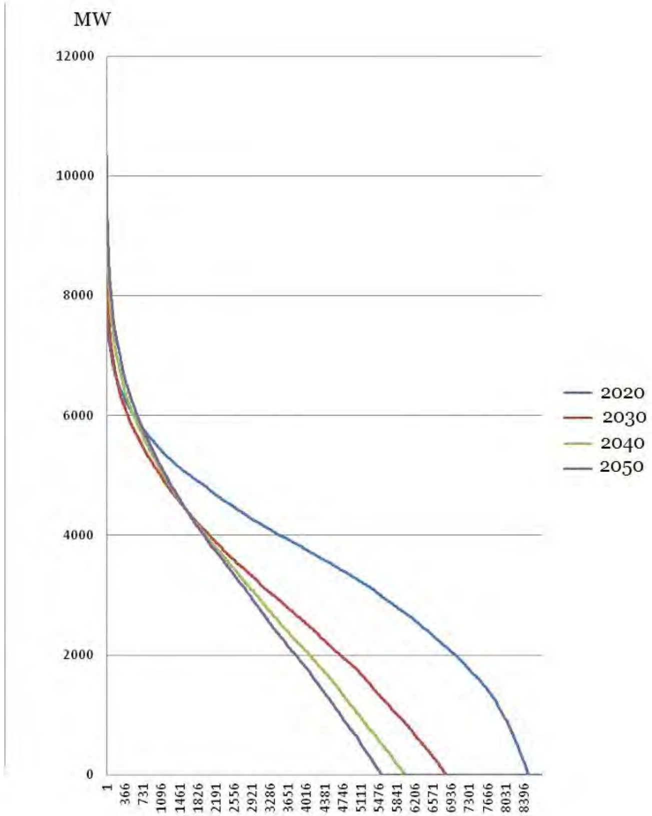
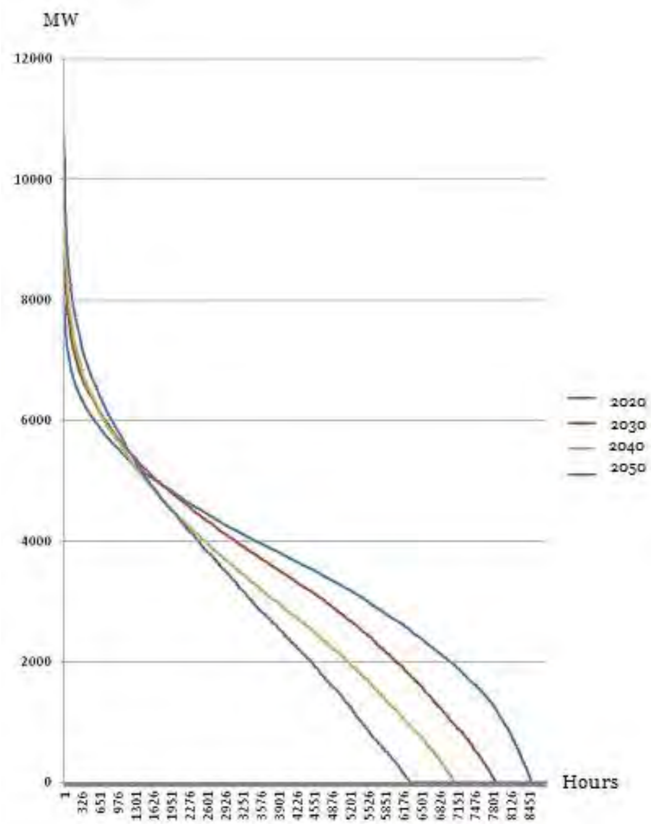


Chart 18: Residual load curves for scenario 4



The Day Ahead Scheduling (DAS) residual loads that need to be covered by thermal, hydroelectric plants and pumping units are given in Table 6, as well as the residual loads to be covered by the thermal units, after the hydro and pumped storage unit loads have been estimated. It goes without saying that the gradual, but extensive, penetration of RES reduces significantly the market share for thermal units, which drops below 10TWh by 2040 in scenarios 2 and 3.

Table 6. Total and residual load per scenario

TWh	2020		2030		2040		2050	
Scenario	Residual demand	Thermal demand	Residual demand	Thermal demand	Residual demand	Thermal demand	Residual demand	Thermal demand
1	30.5	25.9	27.4	22.1	20.3	13.7	15.1	5.6
2-3	30.5	25.9	20.9	12.7	19	8.1	18.2	4.3
4	30.5	25.9	27.5	21.9	23.9	17.3	21.8	9.2

Next, the loading sequence of the units was determined, based on their marginal operating costs. The aim was to calculate both the energy produced by each unit, as well as the hourly System Marginal Price (SMP), assuming that the unit contributions occur on the basis of the operating cost, which is primarily determined by the fuel cost and the CO_2 emissions cost. Subsequently, the cash flows for the two examined units (Ptolemaida-5 and Meliti-2) were analysed, based on the calculated demand for 2020-2030-2040-2050 and using a linear interpolation for the intermediate years.

It should be noted that the analysis concerns constant variables; hence inflation was not taken into account. Additionally, the investment cost for both units was considered the same and equal to the published construction cost, 2,106 €/kW. It was assumed that 25% of the funding derives from PPC's own capital, while the remainder from a 20-year loan at a 7% interest.[65] The same funding terms were also used for the unit conversion to CCS in scenarios 3 and 4.

The main findings of the analysis for each scenario are presented in Table 8. The net pre-tax profitability of the units for each scenario is given in Table 7, In an Internal Rate of Return (IRR) format.[66]

The two lignite units are the cheapest fossil fuel energy production options in all scenarios (including natural gas) in the DAS, based on the marginal production cost. For this reason, the unit production in scenarios 2 and 3 is the same, since their conversion to CCS won't affect their DAS ranking anyway. It should be noted that the natural gas unit conversion to CCS was not taken into account, since the calculations showed that, given the CO_2 emissions and natural gas price levels, there would be no significant economic outcome from the conversion and the lignite units would still be more competitive.

Table 7: Internal rate of return (IRR) for the two units in each scenario

Scenarios	Ptolemaida-5	Meliti-2
Scenario 1	4,9%	10,0%
Scenario 2	-5,4%	2,4%
Scenario 3	1,1%	6,0%
Scenario 4	6,75%	10,7%

[65] The funding terms are taken as assumptions for the purpose of the study. More details regarding the published figures to date can be found in Appendix B.

[66] The Internal Rate of Return (IRR) is a rate of return used to measure the profitability of an investment. The term internal refers to the fact that its calculation does not incorporate environmental factors such as inflation and interest rate swaps.

Table 8: Main results of analysed scenarios

	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Marginal Price (SMP) €/kWh[67]	59.96	80.90	111.66	117.69	63.04	88.76	102.86	112.74	63.04	87.63	100.66	107.51	63.04	87.74	108.65	137.45
Equivalent operating hours																
Ptolemaida-5	8146	7538	6250	4143	8146	6143	5301	2861	8146	6143	5301	2861	8146	7301	6499	5643
Meliti-2	8405	7936	6799	5257	8405	6656	5822	5116	8405	6656	5822	5116	8405	7936	6799	5257
Net produced energy (GWh)																
Ptolemaida-5	5108	4726	3919	2598	5108	3852	3324	1794	5108	3852	3324	1794	5108	4578	4075	3538
Meliti-2	3513	3317	2842	2198	3513	2782	2433	2138	3513	2782	2433	2138	3513	3317	2842	2198
CO_2 emissions (ton/year)																
Ptolemaida-5	5167	4781	3964	2628	5167	3896	3362	1814	5167	390	336	181	5167	463	412	358
Meliti-2	3173	2996	2567	1985	3173	2513	2198	1931	3173	251	220	193	3173	300	257	198
Average generation cost (€/MWh)*																
Ptolemaida-5	52,77	57,70	63,91	72,39	54,38	74,14	87,37	92,10	54,38	46,78	49,54	59,00	54,31	45,23	47,46	48,66
Meliti-2	45,35	49,68	55,08	61,41	46,78	64,25	75,99	75,18	46,78	39,43	41,80	43,05	46,70	37,97	40,32	42,73

***This refers to the operating cost, excluding capital cost.**

[67] System Marginal Price (SMP) is the price at which the electric energy market is determined. It is the price received by all energy suppliers of the system and paid by all purchasers.

The results show the importance of an extended RES penetration and the subsequent reduction of the residual load for the operation of the two units. Their degree of use is radically reduced, dropping to 20-30% in 2050. As a result, the economic performance of the units is also reduced, since the 30-year total revenue does not meet sufficiently the need for significant payoffs, particularly in scenarios 2 and 3, where there is more extensive RES penetration.

Moreover, the high impact of CO_2 emissions prices becomes evident. In scenario 2, where the units aren't converted to CSS but the allowances costs remain high, the investment return decreases significantly, and turns negative for Ptolemaida-5. Things get better in scenario 3, where the units are converted to CCS in 2030, resulting in an important production cost reduction due to the limited need for allowances. This leads to a drop in SMP; however, the all-around economic fluctuations favour the lignite units. Even so, the return rate of the Ptolemaida unit remains at a very low level (Internal Rate of Return 1.1%).

The best performance, for both units, occurs in scenario 4, due to a combined increase in the production of lignite units (due to lower RES penetration and therefore higher residual load), higher SMP weighted-average (due to the increased operating hours of the natural gas units) and the incorporation of CCS technology.

It becomes clear that Meliti-2 performs much better compared to Ptolemaida-5, owing to the higher quality of the fuel and therefore the higher efficiency rate and lower CO_2 emissions coefficients – particularly in the high CO_2 emissions rights cost scenarios (scenarios 2, 3 and 4). Nevertheless, once again, the unit conversion to CCS is a prerequisite, since in any other case the rights cost undermine significantly the investment's revenues.

A rise in the emission rights cost would further limit the operation of the units. In such a case, it is likely that CCS technology would be incorporated in the natural gas units as well, leading to a further drop in SMP and possibly a change in the merit order, with the thermal plants brought in before the lignite units.

Factors not been taken into account

The secondary reserve market, which could, under certain conditions, improve the economic aggregate of the units, has not been taken into account in this study. Furthermore, the role of bilateral contracts – which will be included in a new market plan that is underway- has not been examined in the financial performance of the units, neither have the electricity exports.

Moreover, this study does not address the important technical issues resulting from multiple start/stops of the lignite units, which are expected to occur under a high RES penetration in the system (mostly after 2030). However, these will certainly have a negative effect on the lignite units, favouring the more flexible natural gas ones. The same applies to the necessary interruptions due to unit maintenance works, which haven't been simulated at all, leading to a high use rate of the units during the first years.

Another factor that has been omitted are the likely future storage and demand side management technologies, which could alter demand characteristics in a way that would affect all thermal units, e.g. by altering the hourly fluctuation of the load.

Finally, it should be noted that RES-produced power is fed into the grid as a priority, while energy dumps resulting from network-balance-related issues have not been taken into account. It is assumed that the use of pumped storage systems, as well as other technologies (e.g. smart grids) is likely to solve the RES intermittency problem.

Next, the results of a sensitivity analysis are presented. The analysis concerns the fluctuation of parameters that do not affect the DAS operation but solely the economic performance of the units. As such are considered the unit construction cost, the CCS conversion cost, the loan interest rate and the SMP (taking into account the fact that the units barely determine the SMP).

The calculations show that the performance of the units is largely affected by variations in construction costs (see Table 9). Under certain conditions, a 10% increase is likely to substantially alter the units' performance, as is evident from the Meliti-2 results in scenario 3.

Table 9. Impact of a construction cost increase of 10% on the units' performance (IRR)

	Ptolemaida-5	Meliti-2
Scenario 1	3.7%	8.2%
Scenario 2	-6.4%	0.8%
Scenario 3	0.0%	4.5%
Scenario 4	5.7%	9.2%

Similar variations on the future CCS conversion cost have a very small impact on the units' returns (see Table 10), while, in contrast, the loan interest has an important impact. As can be seen in Table 11, the interest rate variation alone can alter the picture of the investments, since capital cost is a major factor, especially under CCS conversion, compared to the relatively low fuel cost. Finally, the SMP value, and hence the unit revenues, are a decisive factor in the financial nature of the units, as one would have expected (see Table 12).

Table 10. Impact of CCS costs variation (±10%) on the units' performance (IRR)

	Ptolemaida-5		Meliti-2	
	-10%	+10%	-10%	+10%
Scenario 3	1.4%	0.8%	6.3%	5.7%
Scenario 4	6.9%	6.5%	10.9%	10.5%

Table 11: Impact of interest rate variation by±2% on the units' performance (IRR)

	Ptolemaida-5		Meliti-2	
Interest rate	5%	9%	5%	9%
Scenario 1	6,48%	3,3%	12,2%	7,9%
Scenario 2	-3,8%	-6,8%	4,7%	0,3%
Scenario 3	3,2%	-0,9%	8,4%	3,7%
Scenario 4	8,3%	5,1%	12,9%	8,6%

In a nutshell, the core finding of the power-system simulation performed in this study is that the economic performance of the two new lignite units, especially that of Ptolemaida-5, is extremely uncertain, in spite of the favourable assumptions that have been used for both Ptolemaida-5 and Meliti-2 (such as the low CO_2 prices, low emissions reduction targets, absence of lignite use taxation, favourable financing conditions, overlooking additional daily start/stop costs, et al). The combination of the expected high RES penetration, the uncertainty in adopting CCS technology and the implications of the expected CO_2 emissions rights cost, dictate a more extensive dynamic analysis, aiming to fully investigate the sustainability of the lignite units.

THE CONSEQUENCES OF LIGNITE MONOCULTURE IN WESTERN MACEDONIA

The region of Western Macedonia and in particular the Kozani prefecture have been dominated over the last decades by an economic "monoculture": that of lignite mining and combustion, used to produce the largest share of electric energy consumed in the Greek economy. In the prefectures of Kozani and Florina there is a total of 18,000 hectares of lignite mines, which include 6 lignite stations and 17 units of a total capacity of 3,945MW.

The impact of this monoculture on the environment, public health and local communities is described in the following paragraphs.

Air quality impacts

The air pollutants emitted from the power generation units and from the mining and transportation of lignite from the mines to the units, have caused significant air pollution issues in the wider region.

The most important problem is caused by the concentration of PM10 suspended particles. According to the 1999/30 Council Directive, the average daily PM10 concentration shouldn't exceed the 50 μg/m^3 limit for more than 35 days per year (9.6% of total days), while the average annual concentration shouldn't exceed 40 μg/m^3.

According to the Environmental Centre (EC) of the Western Macedonia Region,[68] based on the air quality samples taken from 15 monitoring stations in the Kozani and Florina prefectures, the average annual PM10 concentration ranged between 23-54 μg/m^3 in 2010. The PM10 levels were exceeded by 3% in the settlement of K. Komi, 20% in Kozani, 31% in Ptolemaida, 42% in Florina and reached a peak of 43% in the village of Anargyroi.

The number of samples, average annual value, average daily concentrations variance, number of exceedances and exceedance rate per monitoring station, for the whole period under examination, are presented in Table 13.

Table 13: Average annual concentration of PM10 in μg/m3 and comparison of average daily concentration to concentration limits

REGION	Number of samples	Average annual value (μg/m^3)	Average daily variance (μg/m^3)	Exceedances (>50 μg/m^3)	Exceedance rate (%)
A. Kozani prefecture					
Pentavrysos	365	31	2-154	44	22
Kilada	356	28	1-263	22	6
PPC settlement (Suburb)	364	51	3-230	146	40
Petrana	365	33	5-279	33	9
K. Komi	356	23	1-129	10	3
Ptolemaida	349	44	6-240	109	31
Pontokomi	364	35	3-237	82	23
Kozani	278	38	7-183	56	20
Akrini	258	41	5-117	78	30
Kariohori	253	42	5-173	67	26

[68] "Air quality assessment of the Kozani and Florina region units for 2010" http://energeiakozani.blogspot.gr/2011/01/2010.html

Mavropigi	365	34	2-208	64	18
B. Florina prefecture					
Florina	365	49	5-234	153	42
Vevi	365	25	2-220	17	5
Amindeo	356	27	1-217	20	6
Anargyroi	355	54	1-203	152	43

It is important to note that, during past inspections by the Environmental Inspectors Body, frequent and important violations of the environmental terms and legislation have been registered, and the respective fines have been imposed on the Ptolemaida and Mavropigi lignite mines[69] and on the Ptolemaida lignite plant.[70]

Impacts on public health

Despite the fact that the lignite units and mines have been operating in the Western Macedonia region for over 60 years, it was not until early 2010 that an epidemiological study concerning the health impacts on the local population was assigned to a research team, led by Medical School Professor, Dr. Linou,.[71]

At all events, empirical evidence shows an increased rate of occurrence of air quality-related diseases in the Kozani prefecture, compared to the neighbouring Greneva prefecture, as is also evident from the results of a relevant study[72], presented in Table 14:

Table 14: Respiratory system disease occurrence in children of the Western Macedonia region

Respiratory system disease occurrence in children of the Western Macedonia region (Sichletidis et al., 2005)			
Symptom	**Ptolemaida**	**Kozani**	**Grevena**
Rhinitis	40.3%	35.2%	21.2%
Infectious Bronchitis	12.1%	8.1%	6.7 %
Acute Bronchitis	17%	12.3%	7.1%

At the same time, a study conducted in the Krokos, Aiani and Tranovalto Kozanis villages by the AHEPA Hospital of Thessaloniki found[73] an increase in the number of deaths resulting from thromboembolism by 50%, 43% and 55% respectively, during 1992-2007.

Finally, a study conducted by the Bodossaki General Hospital of Ptolemaida revealed[74] that the allergic rhinitis rate in Ptolemaida is three times the Greek national average.

Of particular interest is a recent analysis[75] by Greenpeace Greece, which made use of the data and methodologies described in the European Environment Agency (EEA) report "Revealing the costs

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[69] Kozani Prefecture, "Environmental Legislation violations at the PPC lignite mines in the Kozani Prefecture", 16.03.2009 http://www.kozani.gr/portal/index.php?option=com_content&task=view&id=644&Itemid=2

[70] Eleftherotypia, "450,000 Euro fine to the PPC registered from the MEECC", 19.08.2010 http://www.enet.gr/?i=news.el.article&id=194529

[71] Linou A., Riza E., "Epidemiological study in the Kozani prefecture", presentation http://www.kepekozani.gr/pdf/parous_meletis.pdf

[72] Sichletidis et al, "The effects of environmental pollution on the respiratory system of children in Western Macedonia, Greece", 2005 http://www.jiaci.org/issues/vol15issue02/6.pdf

[73] Kathimerini, "Incontestable evidence that pollution kills", 15.09.2007 http://news.kathimerini.gr/4dcgi/_w_articles_ell_620920_15/09/2007_241382

[74] Ethnos, "Allergy… disease in Kozani", 10.05.2010 http://www.ethnos.gr/article.asp?catid=23106&subid=2&pubid=11815044

of air pollution from industrial facilities in Europe".[76] According to the analysis, the air pollution caused by the Western Macedonia lignite units was responsible for 461 deaths in 2009 and for the loss of 1,113,176 work days.

Impacts on water resources

The effect of the operation of the lignite units and their cooling needs on the water resources of the region is also very important. The PPC decided recently to cover the water needs of the Amindeo and Ptolemaida power stations using the Polifitos Lake, fed by the Aliakmonas River. This translates into an annual increase of 17 million m^3 (55 million m^3 to 72 million m^3) of water drained from the river by the PPC. It is remarkable that these huge quantities of water are transported along a 60km distance uphill, covering an altitude of 390 meters. In comparison, for the water needs of the population in the whole region 43 million m^3 are required.

In December 2012, EU Commissioner Potočnik, replying to a relevant question in the European Parliament stressed that[77] "*The Greek authorities have to identify adequate measures in the Aliakmonas River Basin Management Plan, as required by Directive (WFD 2000/60/EC(1)), to ensure satisfactory standards of all its waters by 2015*", adding that "*Greece hasn't reported its River Basin Management Plans (RBMPs) to the Commission. The Commission has therefore opened an infringement procedure against Greece, for failing to adopt and report its RBMPs*".

The PPC used the Vegoritida lake water until 1997, which resulted in a lake level drop of approximately 30 meters and an 80% loss of total volume. At the same time, heavy water degradation has been noted due to the deposit of pollutants (e.g. heavy metals).[78]

As with surface water, dramatic groundwater depletion has also been observed in the Sarigiol basin (adjacent to the Ptolemaida mines). The Municipal Company of Water Supply and Sewage of the Kozani prefecture has filed a lawsuit against the PPC, claiming €16.5 million, due to the major economic damage caused by groundwater depletion, after having to invest in alternative water supply sources of a considerably higher cost, in order to cover the needs of the town.[79]

Relocation of Settlements

Many settlements in the Western Macedonia Region have been forced to relocate as a result of the mining activities of the PPC, and this has had important economic, social, cultural, spatial planning and technical consequences.

Kardia – after which the Kardia lignite unit was named - was the first village of the Region to be relocated. The relocation began in 1972 and was completed in 1976, involving a total of 692 people. In 1979, 300 people were relocated from the Eksohi settlement and 1,228 people from the Haravgi village. The Komanos inhabitants began relocating in 1999 and by 2003 almost all of them had left. However, a new settlement was never constructed. Today, in the area designated for the new village, there stands only a church.

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[75] Greenpeace, "Greece's seven wounds", 03.2012 http://www.greenpeace.org/greece/Global/greece/image/2012/climate/dei/img/20120214_Human_and_economic_cost_of_lignite.pdf

[76] EEA 2012, "Revealing the costs of air pollution from industrial facilities in Europe", http://www.eea.europa.eu/pressroom/newsreleases/industrial-air-pollution-cost-europe

[77] Reply of the EU Commissioner Potočnik to a question by MEP N. Chrisogelos http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+WQ+E-2012-009430+0+DOC+XML+V0//EL

[78] Region of Western Macedonia, Telemetry System for Monitoring Underground Water Reserves in Ptolemaida Basin http://www.aquasensin.gr/Default.aspx?pid=35&la=2

[79] Kozan.gr, "Kozani MCWSS claims €16.5 million in lawsuit against the PPC", http://dev.kozan.gr/?p=9638

The latest example of villages that have been relocated is that of Klitos. The relocation began in 2000. However, even today, the inhabitants have not been offered a sustainable settlement, since the new village – just outside Kozani – faces many issues as a result of incomplete infrastructure.

Nowadays, the relocation of Pontokomi and Mavropigi villages is in process, while it has also been decided to relocate Akrini and Agioi Anargyroi.

The involuntary expropriation and relocation of the two settlements was decided by the PPC (154/22.07.2008 act), in order to exploit the underground lignite reserves on grounds of national interest.

Pontokomi covers an area of 887,230.56 m^2. On 23/9/2008, following a referendum, the municipal council of Dimitrios Ipsilantis chose to relocate the village to the ZEP area of the Kozani municipality,. On 24/01/2012, the expropriation decision was published in the Government Gazette.

Mavropigi is built on a 415,000 m^2 area. Following an inhabitants' referendum, it has been decided to move the village to the Kouri Ptolemaidas area. For the time being, Mavropigi faces – apart from all the other consequences arising from adjoining a lignite mine - a major ground-stability issue. A large crack has been created that runs through the village, forcing a large number of inhabitants to abandon the village, either on receiving compensation from the PPC or at their own expense. On 14/09/2011, the expropriation decision was published in the Government Gazette.

Today both cases await a judicial verdict on the expropriation compensation. The Kozani Court of First Instance defined the expropriation compensations for Mavropigi on 14/2/2013.[80] Within the next 18 months, the PPC is obliged to deposit the sums to the Deposit and Loans Fund of Greece and hence confirm the purchase of the village. The court case for Pontokomi has not yet been scheduled, the responsibility resting with the PPC; it is expected, however, that the PPC will begin developing the 135 hectares of land near the settlement by April, ignoring its earlier commitments to await the outcome of the trial; this has also been confirmed in an open letter sent to the PPC by the Kozani municipality.

The cases of the Akrini and Agioi Anargyroi villages differ from the previous ones, as there are no lignite reserves under them. According to the law, the mines can be as close as 250 meters to inhabited areas. As a result, both these settlements adjoining lignite extraction and deposition areas, are subject to heavy pollution and a dramatic decline in living standards, but nevertheless no obligation arises for their relocation. Following an intense struggle by the local community, the relocation of the settlements was included in the 3937/2011 law, article 28. According to that decision, the PPC bears only 50% of the cost and the Greek State the other half.

The only development since then has been the Akrini inhabitants' decision to choose as their relocation area the Kozani ZEP region, after holding a referendum on 1/7/2012.

The expansion of PPC activities places constant and extreme pressure on other settlements as well. A study on the Mavrodendrio settlement pointed out the deteriorating living standards that the village is experiencing and predicted further degradation in the years to come. Similar pressure is exerted to other settlements (Proastio, Ag. Dimitrios, etc.).

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[80] Environment and Quality of Life Union of the Dimitrios Ipsilantis municipality, "The Mavropigi expropriations at the Kozani Single-Member Court of First Instance…" 15.02.2013 http://pontokomicom.blogspot.gr/2013/02/blog-post_9735.html

THE TRANSITION TO A POST-LIGNITE ERA

The Technical Chamber of Greece/WMD study

In July 2012, the Western Macedonia Department (WMD) of the Technical Chamber of Greece (TCG) published the study: "Cost estimation of a Western Macedonia transition to a low-lignite production status quo".[81] The aim of the study is, according to the introduction of the then president of the TCG/WMD administration: "*to calculate the economic implications and synergies between the lignite industry and the local community, without dealing with the undeniably major issues of environmental pressure and degradation*".

The main point made in the study is the view that "*there is a clear disagreement between the national or international interest and the local cost*", while there is reference to winding down the use of lignite by the Greek state.

In chapter 3 of the study, the positive impacts of lignite activity are presented, which are divided into direct (jobs, payrolls etc.), indirect (investments, goods, regional activities etc.) and derivative (wealth and jobs resulting from the income of the workers in the lignite industry).

The conclusions of the TCG/WMD study

Chapter 6 of the TCG/WMD study states the following:

- For every one permanent job position in the mines and production stations, there are 3.28 created and preserved in the local job industry. For every €1 spent by the PPC on salaries and contract works, more than €3 are added to the local economy business cycle inductively. Hence, the 6,882 permanent and temporary PPC jobs in the Western Macedonia region, create 22,573 additional jobs. The annual net dispensable income of the PPC employees along with all the contract works and services towards the mines and the production stations sum up to €387 million and create a wealth worth €1,198 million for the whole of the local economy. In effect, over 25% of the Regional GDP results univocally from the productive activities of the lignite industry.
- The decommissioning of 300 MW of lignite capacity in the region will deprive €83 million annually from the local economy and will cause a loss of 1,559 jobs mainly outside the PPC. If 2,400 MW are decommissioned, without any support measures for the local economy, the magnitude of the consequences might prove dreadful and irreversible for the region.
- The cumulative lignite value that has been mined from 1960 until 2011 has produced a total wealth of €35 billion for the Western Macedonia region. The exploitation of the remaining lignite reserves will contribute an additional €20 billion until 2054, year at which the withdrawal of the last lignite unit in the area is expected.
- At a national economy level, the lignite deposits that have been extracted in the area from 1960 to 2009, produced an equivalent of 562,000 GWh of electric energy, it prevented the import of 154 million tons of oil equivalent and contributed $49.7 billion of currency savings to the national economy.

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[81] TCG/WMD "Cost estimation of a Western Macedonia transition to a low-lignite production status quo", 07.2012 http://tdm.tee.gr/images/stories/Docs/nea_anakoinoseis/deltia_typou/ektimisi_tou_kostous_metabibasis_ths_dm.pdf

The primary and fundamental flaw of the study – also acknowledged by its writers – is that it doesn't take into account the negative economic impacts resulting from the lignite activities in the area, a flaw that inevitably creates an idealised view of lignite monoculture. Moreover, such a study would only be useful if it carried out a comparative analysis of alternative development options for the region, where no direct or indirect cost would remain hidden.

More specifically, even if the global consequences of lignite production are not taken into account, as is the case, and attention is only drawn to local consequences, the study should also account for:

- The cost of the fuel itself (for which the PPC pays virtually no extraction rights)
- The cost to public health resulting from the operation of the mines and units
- The cost of soil disturbance resulting from the construction of the mines
- The cost resulting from the destruction of the area's water reserves

The aforementioned study of the Harvard Medical School,[82] which focuses on the coal production areas of the Appalachians, concluded that the local impact cost resulting from coal excavation, transportation and burning ranges between 83-162 $/MWh, with the optimal estimation being 147 $/MWh. The application of these figures to the Western Macedonia region (562 million MWh of electricity production) leads to a total economic cost for the past decades of $82.6 billion.

This fundamental deficiency of the study – the lack of comparative analysis of alternative options – also affects the assessment of the impact of lignite monoculture on the job sector in the region. It would be useful if the study also estimated the jobs *not* created or lost in other economic activities, such as agriculture, livestock rearing, tourism, crafting etc. as a result of the PPC activity, as well as the cost of the reorientation of the local economy towards the post-lignite era transition, which will take place sooner or later.

As far as employment is concerned, the study fails to make any reference to one of the main characteristics of the Western Macedonia Region, the fact that it consistently holds the first position amongst Greece's 13 regions in terms of its unemployment rate – in fact, in 2011 it had the 9th highest unemployment rate amongst all 271 regions of the EU.[83] Taking this into account, it is particularly interesting that the Kozani prefecture is consistently second in highest declared incomes in Greece, behind Athens.[84]

The bias of the study in favour of lignite also becomes apparent in its reference to international experience. Only cases where negative outcomes have resulted at a local level from the reduction of lignite/coal activity are being cited, despite the fact that there is extensive literature and experience of regions in Belgium, Germany or Spain, which clearly benefited from their transition to a coal-free future.

Finally, the study seems to ignore the legally-binding national and European commitments of the country, such as, for example, the 40% target of renewable energy contribution in the electricity mix by 2020. In October 2012, the TCG/DWM published another study titled "Assessment and Designation of the Post-Lignite Era for the Energy Centre of Western Macedonia".[85] In this study, a series of proposals are made, not for planning the transition to a post-lignite era in the Region

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[82] P. Epstein et al, "Full cost accounting for the life cycle of coal" http://solar.gwu.edu/index_files/Resources_files/epstein_full%20cost%20of%20coal.pdf

[83] EUROSTAT, "Unemployment in the EU27 regions", 04.07.2012 http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/1-04072012-BP/EN/1-04072012-BP-EN.PDF

[84] Express, "The first consequences of the memorandums are depicted in the 2010 declared incomes", 13.01.2013 http://www.express.gr/news/finance/676458oz_20130113676458.php3

[85] TCG/DWM "Assessment and Designation of the Post-Lignite Era for the Energy Centre of Western Macedonia" http://tdm.tee.gr/images/stories/Docs/nea_anakoinoseis/theseis_paremvaseis/tee_tdm_prosdiorismos_oriothetisi_meta lignitikis_epoxis_gia_energeiako_kentro_dyt_makedonias_final_20_11_2012.pdf

(as the title suggests), but for the prolongation of lignite activities. As an example, the proposals include introducing natural gas for firing and co-firing the lignite units, the exploitation of lignite in non-electrical uses for the production of liquid fuels, and the import of lignite from FYROM, Albania, and Serbia and "*definitely from the areas of Elassona and Drama*".

Green jobs in the energy sector

Supporters of lignite often argue that the excavating and burning processes provide many jobs, at least compared to other power generating alternatives . However, international experience shows otherwise.

At first, there is an enormous job opportunity potential in the energy saving sector. According to the "**Energy Efficiency Plan 2011**" of the European Commission (2011)[86], the implementation of the proposed measures will create up to 2 million jobs. These are jobs in the energy upgrade of buildings, the development of new products and the increase of industrial efficiency, the sectors, in other words, that have been hit most by the recession. A typical example is that of Germany, where since the application of the energy upgrade of buildings programme in 2006, €100 billion have been spent in investments and 300,000 jobs have been created or preserved in the construction sector.[87]

At the same time, the renewables sector in Europe has also shown important growth as far as job creation is concerned. According to the "Towards a job-rich recovery" publication of the European Commission (2012)[88], there are 1.4 million people working in the RES sector today across the EU (0.7% of the total EU workforce), which will reach roughly 2.8 million if the 2020 target is met, and 3.4 million in 2030. Germany provides one more valuable, positive example: employment in the RES sector jumped from 170,000 employees in 2005 to 380,000 in 2011, while the German RES Federation estimated that by 2020 it might reach 500,000.[89] It is notable that during the same period the number of employees in the fossil fuel sector, including those in coal mining, dropped slightly from 175,000 to 155,000.

Finally, employment can be positively affected through the additional public revenue that will result from the auctioning of emissions rights for facilities that fall under the EU ETS and through taxation in other sectors. In the aforementioned publication of the Commission, it is estimated that a recycling of revenues -in order to reduce labour taxation- could potentially increase employment in the EU by up to 1.5 million jobs by 2020.

Similar experiences can be found in the USA, a country which has been left behind in the advancement of clean energy compared to the EU. In a recent release, the Labour Statistics Bureau of the US government announced that there was a four-fold increase in job creation in the energy sector compared to the average in the economy (4.9% compared to 1.2%), reaching a total of 3.4 million employees.[90]

In 2012, The Environmental Entrepreneurs organisation studied the 300 largest clean energy and clean transportation projects announced in that year in the USA and estimated that 110,000 jobs were created.[91] Through the study of such employment data, Prof. Robert Pollin of the University

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[86] European Commission, "Energy Efficiency Plan 2011"08.03.2011 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF

[87] ILO, "Working towards sustainable development: Opportunities for decent work and social inclusion in a green economy", 12.06.2012 http://www.ilo.org/global/publications/books/WCMS_181836/lang--en/index.htm

[88] European Commission, "Towards a job-rich recovery", 18.04.2012 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2012:0092:FIN:EN:PDF

[89] The German Energiewende, "Stimulating technology innovation and the green economy" http://energytransition.de/2012/10/1-iii-stimulating-technology-innovation-and-the-green-economy/

[90] Bureau of Labor Statistics, "Green Goods and Services Summary", 19.03.2013 http://www.bls.gov/news.release/ggqcew.nr0.htm

[91] http://www.e2.org/ext/doc/E2CleanEnergy2012YearEndandQ4.pdf

of Massachusetts-Amherst estimated that by investing $1 million in wind or solar energy there are twice as many more jobs created, compared to similar investments in coal or natural gas[92]. In fact, the impact on employment is almost triple if the investment is in the energy upgrade of buildings and almost quadruple if investment is in public transport.

A related study conducted by Berkeley researchers agrees with the above, stating that, apart from the high employment to investment ratio, RES also outperform fossil fuels in employment per KWh of energy generated.[93]

[92] CleanTechnica, "Over 3 Times More Green Jobs Per $1 Invested Than Fossil Fuel Or Nuclear Jobs", 20.03.2013 http://cleantechnica.com/2013/03/20/over-3-times-more-green-jobs-per-million-than-fossil-fuel-or-nuclear-jobs/

[93] M. Wei et al, "Putting renewable and energy efficiency to work: How many jobs can the clean energy industry generate in the US?", Energy Policy 38, 2010 http://rael.berkeley.edu/sites/default/files/WeiPatadiaKammen_CleanEnergyJobs_EPolicy2010.pdf

APPENDIX A

Economic Analysis Methodology

The main parameters that affect the financial sustainability of the thermal units and are part of the Day Ahead Market are:

- The investment cost and capital cost
- The fuel cost
- The CO_2 emissions rights cost
- The System Marginal Price (SMP)
- The energy delivered to the system

The other parameters used in the economic analysis such as variable cost, maintenance cost etc. are mostly related to the technology of the unit, and can be considered as unaffected by external factors, thus retaining known and fixed values.

From the above list, the last two parameters require further investigation, as they depend on the overall development of the electricity market and on other factors, such as the CO_2 emissions cost and the fuel cost. For example, the SMP depends on the electricity demand, the RES penetration and the type of thermal units available at a given time.

As a result, it was deemed necessary to estimate these parameters using a more inclusive method, which takes into account the correlation of variables in the power system, through a simplified simulation method of the electricity system. The ultimate aim is to estimate the energy delivered by the lignite units and the SMP, thus allowing for the income time series to be calculated. This was achieved through the following:

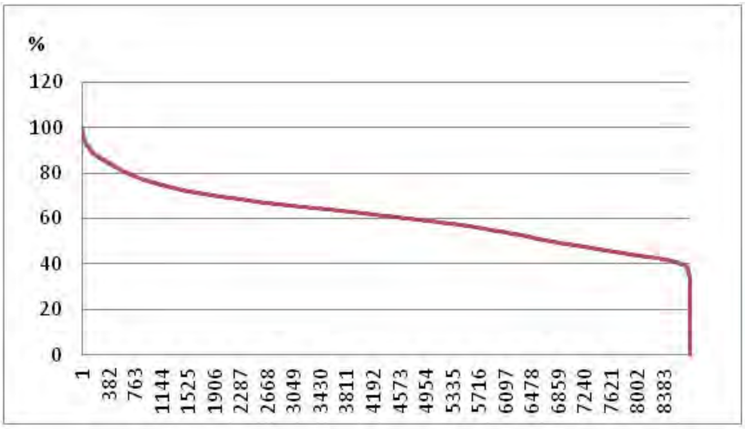
- The total electricity demand and the load curves are calculated
- The RES power is determined
- The RES energy is deducted from the demand, in order to calculate the demand curve of the thermal units
- The thermal units that participate in the Day Ahead Market are determined
- Using the merit order curve for the thermal units, the level of usage is determined, as well as the operating time and the resulting SMP based on the given power demand.

These steps were followed for the years 2020, 2030, 2040 and 2050, which mark the duration (2020-2050) of the economic assessment of the operation of the units. Linear interpolation was used for calculating the respective parameters for the intermediate years.

For the total power demand, the data given in the Greek "Energy Roadmap to 2050" was used. The demand scenarios chosen were the BAU and the MRES-60%. It should be borne in mind that the aim of the present study is not to produce scenarios for the development of the power system, but to investigate the economic performance of the lignite plants under various conditions and assumptions. On that account, the capacity of the various RES technologies was taken from the data of the same study.

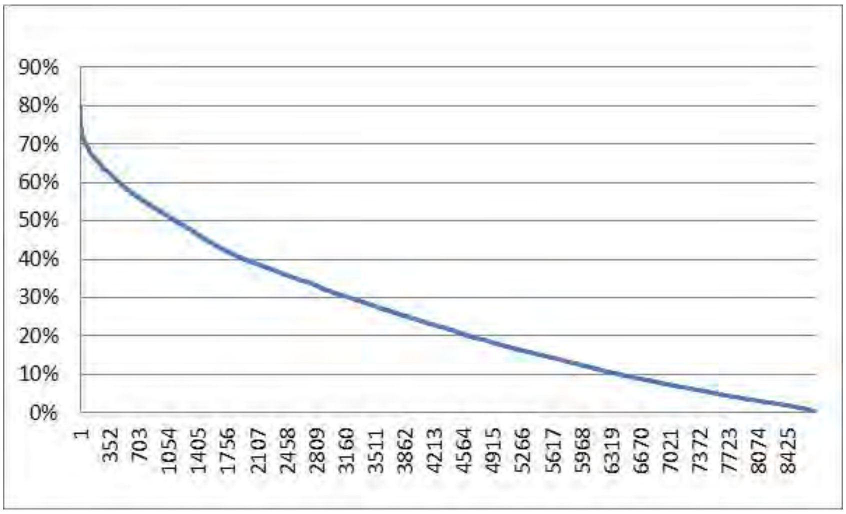
For the determination of the capacity curve of the system, figures from the ENTSO-E database were used for the years 2010-2011, which are based on IPTO data, while it was assumed that the load duration curve shape remains the same throughout the years.

Chart A. 1: Normalised load duration curve



The next step is to determine the residual load duration curves, i.e. the load that the thermal units will have to cover once the RES production is deducted, assuming that the energy generated by them will be given priority. For this purpose, the following procedure was followed. First, the hourly production of wind parks was calculated, using published data found on the RAE website[94] (2009-2010) and assuming that the hourly generation pattern remains practically the same (Chart A.2)[95]. The same procedure was followed for the PV generation, using hourly, per month, production rates, as provided in a HTSO[96] (Hellenic Transmission System Operator SA) report (Chart A.3). Based on the same study, the generation profile of small hydroelectric units was determined, using monthly load coefficients (Table A.1). For the solar thermal units, the approximate hourly production curves for winter and summer were used, based on data available in the literature[97] and assuming that the units will incorporate thermal storage systems (Chart A.4).[98] The geothermal and biomass unit production was taken as constant, using capacity coefficients of 80% and 85% respectively.

Chart A. 2: Normalised wind station power curve (RAE)



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[94] RAE announcement, 16.07.2010 http://www.rae.gr/old/cases/wind_production_2009/index.html

[95] This assumption does not conform with reality, since the introduction of new wind farms will modify the aggregate production curve; it has been used due to lack of other data.

[96] HTSO, Wind Production Absorption Potential in the Peloponnese, Nov 2009

[97] WB, Assessment of Technology Options for Development of Concentrating Solar Power in South Africa, 2010

[98] The thermal units are designated mainly for South Peloponnese, Crete and the Dodecanese. It was assumed that the projects carried out will be large parabolic trough units or solar towers.

Chart A. 3: PV systems capacity curves (HTSO, 2009)

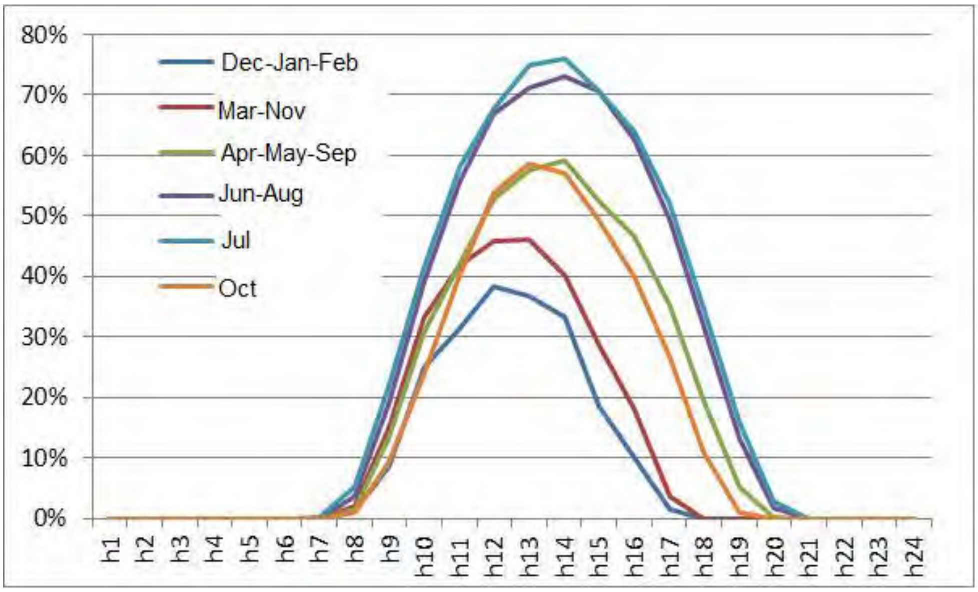
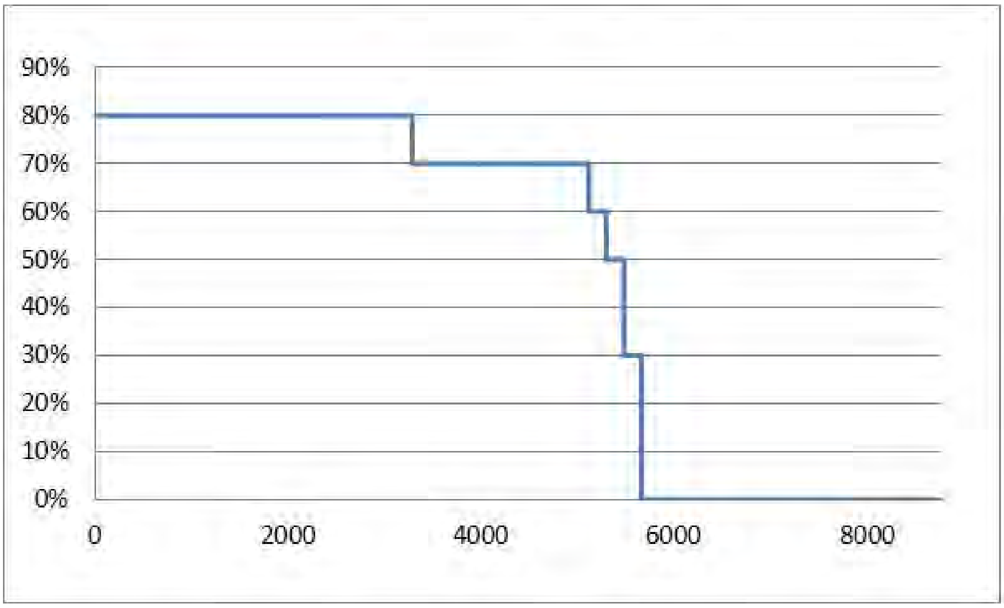


Table A. 1: Capacity coefficient for small-scale hydro (HTSO, 2009)

Month	Capacity Coefficient	Month	Capacity Coefficient
January	60%	July	30%
February	66%	August	24%
March	67%	September	24%
April	61%	October	37%
May	52%	November	45%
June	39%	December	50%

Chart A. 4: Solar thermal stations normalised load curve (WB data, 2010)

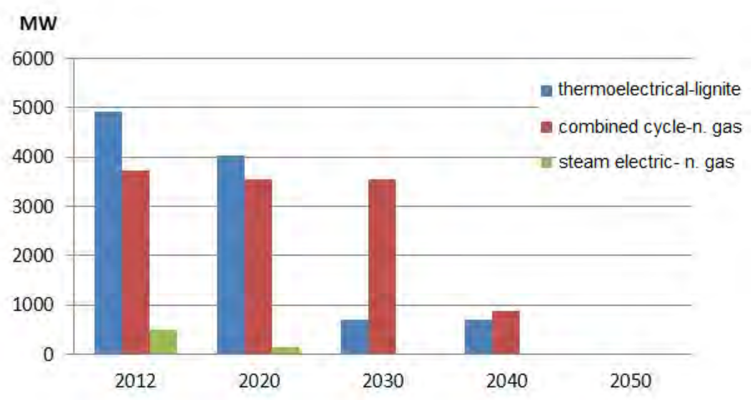


For the large hydro stations and pumping systems a different approach was followed. At first, it was assumed that the pumping systems will absorb the energy rejected from the RES units, so that they can deliver it to the system and, thus, limit the costly peaks. Once the discharged energy was calculated, the appropriate peaks of the system were determined, at which the energy was released, using a coefficient of 50% (i.e. it was assumed that, every hour, 50% of the pumped storage capacity can be made available). A similar procedure was then followed for large hydro plants, i.e. delivering the energy at peak hours but considering different seasonal load factors.

Using this method, the residual load that the thermal units of the system need to cover was calculated.

The next step was to assess the sequence of use of the thermal power plants. At first, using IPTO figures, it was possible to determine which units will be operating and those that will have been withdrawn.[99] In case no data was available, estimates were made using the date on which the units were connected and their lifespan (30 years for natural gas units). The results can be seen in Chart A.5. The next step was to calculate the capacity of each technology using screening curves, in order to minimise the generation cost of the remaining demand. By taking into account the existing and remaining units, the capacity of each technology in the future system was also estimated.

Chart A. 5: Development of capacity of the installed thermal units (IPTO 2012 and estimates)



The eligible technologies that were analysed using this method are presented in Table A. 2, while their techno-economic features, taken from recent IEA[100] publications, are given in Table A. 3.

Table A. 2: Power generation technologies used

Description of technology	Code
Supercritical pulverized lignite station	SC-PC
Ultra-supercritical pulverized lignite station	USC-PC
Lignite gasification station	IGCC
Natural gas combined cycle station	NGCC
Natural gas steam turbine station	GT
Supercritical pulverized lignite station with CCS	SPC-CCS
Ultra-supercritical pulverized lignite station with CCS	USC-PCC-CCS
Lignite Gasification station with CCS	IGCC-CCS
Natural gas combined cycle station with CCS	NGCC-CCS

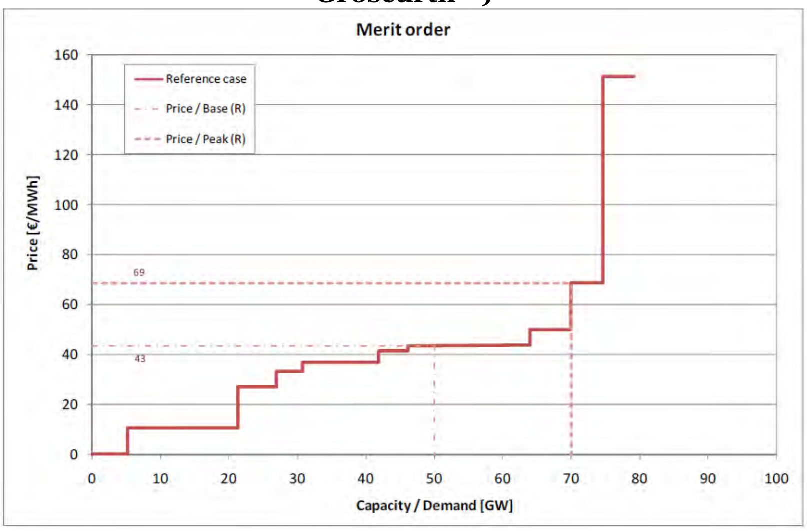
[99] IPTO, Ten Year Network Development Plan 2014-2023, Dec 2012
[100] OECD/IEA, Energy Technology Perspectives 2010, 2010

Table A. 3: Techno-economic development of thermal units (Source: IEA 2010)

Technology	2020			2030		
	Capital cost €/kW	Operational cost €/kW	Efficiency %	Capital cost €/kW	Operational cost €/kW	Efficiency %
SC-PC	1420	29	42%	1339	26	42%
USC-PC	1482	30	48%	1393	28	49%
IGCC	1616	49	45%	1518	46	48%
NGCC	616	19	59%	589	18	60%
GT	464	11	33%	464	11	33%
SPC-CCS	2171	65	34%	2026	60	34%
USC-PCC-CCS	2268	68	38%	2107	64	40%
IGCC-CCS	2152	65	37%	2018	61	41%
NGCC-CCS	974	29	51%	911	28	53%
Technology	**2040**			**2050**		
	Capital cost €/kW	**Operational cost €/kW**	**Efficiency %**	**Capital cost €/kW**	**Operational cost €/kW**	**Efficiency %**
SC-PC	1259	25	42%	1179	23	42%
USC-PC	1304	26	51%	1214	24	52%
IGCC	1420	43	51%	1321	40	54%
NGCC	563	17	62%	536	16	63%
GT	464	11	33%	464	11	33%
SPC-CCS	1879	56	35%	1733	51	36%
USC-PCC-CCS	1946	59	42%	1786	54	44%
IGCC-CCS	1884	57	44%	1750	53	48%
NGCC-CCS	849	26	54%	786	24	56%

Based on the remaining units and the theoretical capacity of new thermal units, the merit order curve is determined, through the use of which the SMP and the load level (production) of each unit are calculated.

Chart A. 6: Example of a thermal units' merit order curve, for the German system (Source: Groscurth[101])



[101] Groscurth H., The economic viability of hard coal power plants demonstrated on the example of the planes hard coal fired plant in Mainz, 2010

The above methodology resulted from the need to study the operation of the existing lignite units throughout their economic lifespan (30 years), by taking into account the correlation between the main cost and operation parameters of the units and the wider configuration and operation of the electricity system. By and large, it is an attempt to simulate the operation of the system in order to produce plausible operating scenarios and, sequentially, to investigate the economic performance of each unit. Despite the obvious deficiencies, mostly related to the hourly operation of the thermal units and the required start/stop time intervals, the methodology has a satisfactory degree of detail and reveals the important role of elements such as the extensive RES penetration, the emissions rights cost and the competitive thermal units.

APPENDIX B

Financing the unit

The particular financial state of the PPC means that it is not in a position to cover the investment cost for the Ptolemaida-5 unit through its own resources.

In an announcement made on 13th March 2013, the corporation states that:[102]

"*Regarding debt, and the partial funding of the project, the Company aims to turn to funding mechanisms such as syndicated loans, which will be covered by an international Export Credit Agency (ECA) and/or bilateral loan contracts with commercial banks and/or international organisations.*

In addition, the Company can be financed through issuing bonds in the national or international markets and it is part of the general plan of the Company to access these markets, under appropriate conditions.

With respect to own funds, due to the importance of the project (Board of Directors Decision 247/12), the Company believes that it can finance the project to a large extent through private equity, by a proper management of its investment plans and cash flow generation, without excluding the possibility of approach the capital markets in the construction phase of the project."

According to reports[103], the PPC will cover 38% of the investment cost using its own funds. It aims to receive guarantees from the German government for loans provided by the KfW German investment bank and the Hermes financial mechanism to cover 44% of the cost; for the remaining 18% the goal is to receive a loan from the European Investment Bank (EIB). German and Greek NGOs (Urgewald, Climate Alliance, WWF, and Greenpeace) have denounced[104] the possibility of using favourable German financing mechanisms for such a polluting investment, while they have also targeted the EIB for the same reason.[105] In a recent open letter[106] towards the EIB and the European Bank for Reconstruction and Development (EBRD), 98 NGOs call for the prevention of granting yet another loan for financing fossil fuels and to examine more carefully the alternatives, instead of accepting the claims of project sponsors.

The likelihood of KfW and Hermes funding the unit was also questioned by MPs of the Alliance '90/The Greens party in the German Parliament.[107]

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[102] PPC, Clarifications on the item of the agenda of the EGM on 29/03/2013, www.dei.gr

[103] EnergyPress, "Ptolemaida 5 also hinges on the troika", 30.08.2012 http://www.energypress.gr/news/Apo-thn-ekthesh-ths-troikas-kremetai-kai-h-Ptolemaida-5

[104] WWF- Greenpeace, "Loan to the PPC with a lignite "flavour"", 04.09.2012, http://www.wwf.gr/index.php?option=com_content&view=article&id=937:-lr-&catid=70:2008-09-16-12-10-46&Itemid=90

[105] Bankwatch, "Energy lending for people and planet" http://bankwatch.org/campaign/energy-lending

[106] NGO open letter towards the EIB and the EBRD, "Sostanj must never happen again", 20.03.2013 http://bankwatch.org/sites/default/files/letter-EBRD-EIB-Never-again-Sostanj-20Mar2013.pdf

[107] Minutes of the Federal Parliament of Germany, 10.08.2012 http://dipbt.bundestag.de/dip21/btd/17/104/1710463.pdf

APPENDIX C

CO_2 capture-transport-storage – The PPC study and the 2009/31/EC Directive requirements

Carbon capture and storage technology (CCS) is considered, particularly by fossil fuel supporters, a promising technology towards a transition to a zero-greenhouse gases emissions energy system. In fact, according to a related IPCC study[108], CCS technology could contribute by as much as 10-55% to the global effort for the reduction of greenhouse gas emissions. The European Commission notes in the Energy Roadmap to 2050 that in all scenarios examined "*for all fossil fuels, carbon capture and storage technology will have to be applied from around 2030 onwards in the power sector*".

Such a perspective remains, however, meaningless for the time being, due to major techno-economic difficulties, excessive energy consumption, and legal uncertainty as far as storage, security and accidental CO_2 leak management issues are concerned. Besides, CCS technology application studies rarely conduct risk assessments, which are deemed, however, necessary given the lack of experience in large-scale applications.

It is worth mentioning that during the first round of calls under the NER300 funding programme of the European Commission and the European Investment Bank, which funds awards of a total value of €1.2 billion, out of the €275 million envisaged for CCS applications, no project received funding since no EU member state chose to support it.[109] Today, there is only one large-scale thermal power station equipped with CCS technology in full operation, in Mongstad, Norway, which received a $1 billion subsidy from the Norwegian government.[110] [111]

Given the current failure in developing CCS systems, the European Commission will put forward new regulations which reportedly[112] will include either emissions performance standards or mandatory CCS certificates, or a combination of both.

The existing European legal framework for CCS is the 2009/31[113] Directive which was adopted by the national legislature through the 2516/B'/7.11.2011 OGG Joint Ministerial Decision. According to article 33 of the Directive, operators of all combustion plants should examine whether the following conditions are met:

- suitable storage sites are available,
- transport facilities are technically and economically feasible,
- retrofitting for CO_2 capture is technically and economically feasible.

In order to comply with the above legislation, the PPC produced a techno-economic study for the operation of a CO_2 capture, transport and storage system in the planned Ptolemaida-5 unit.

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[108] IPCC Special Report on Carbon Dioxide Capture and Storage, 2005 http://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf

[109] European Commission, "Commission awards EUR 1.2 billion to kick-start 23 innovative renewable energy projects", 18.12.2012 http://europa.eu/rapid/press-release_IP-12-1385_en.htm

[110] Global CCS Institute, The global status of CCS, 2012, http://cdn.globalccsinstitute.com/sites/default/files/publications/47936/global-status-ccs-2012.pdf

[111] MIT, Power Plant CO2 Capture and Storage Projects http://sequestration.mit.edu/tools/projects/index_capture.html

[112] Euractiv, "Brussels steers towards resolute new CCS targets by 2014", 15.01.2013 http://www.euractiv.com/climate-environment/brussels-steers-resolute-new-ccs-news-517045

[113] Directive 2009/31 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF

The study estimates the overall CO_2 capture cost at 38.41€/tCO_2, with the calculation break-down given in Table C. 1.

Table C. 1: CO_2 capture cost

Type of cost	Cost (€/t CO_2)
Post-combustion process	17,46
Amine substitution cost	1,79
Investment cost	12,97
Operation and maintenance cost	6,19

Regarding the transport of CO_2, the PPC study examines two options, depending on the storage location. The first option is transporting it to a western area of Thessaloniki using 106 km. of pipes, at a 1.06 €/tCO_2 cost. The second option, in case the MEECC does not give permission for CO_2 storage within Greek territory, would be to transfer it by sea. It would then be used in hydrocarbon extraction, as part of the enhanced oil recovery method, at an estimated cost of approximately 21.92 €/tCO_2.

It should be emphasised, though, that this transport method hasn't been applied on this scale anywhere in the world; it requires considerable infrastructure, such as transport pipes, CO_2 refrigeration-liquefaction units, temporary storage facilities, transport ships, a port constructed or modified to meet CO_2 transport requirements and an unloading system.

Figure C. 1: CO_2 transport from the Ptolemaida-5 unit, to western Thessaloniki (PPC, 2011)

With regards to the CO_2 storage system, an analysis of the geological potential, conducted by IGME (Institute of Geology and Mineral Exploration), concluded that the evaluated geological basin is a saline aquifer. In the study, the PPC estimates that the total CO_2 to be stored is about 19.5% of the overall underground capacity of the basin, which is below the lower boundary (20-30%) of the rated storage capacity which is considered suitable for CO_2 storage – based on previous experience of using storage technology for such quantities, as the researchers note. Finally, the PPC study estimates the storage special cost at 2.11 €/t CO_2.

To sum up, according to PPC estimates, the total installation and operational cost of the CCS system, if CO_2 is to be stored within Greek territory, amounts to 41.58€/tCO_2.

It should also be noted that, according to the study, once the CCS system becomes operational, the unit efficiency will drop from 41.5% to 30.1%.

As far as the CCS licensing procedure is concerned, it is not possible to confirm at this preliminary stage whether the PPC would gain MEECC approval for meeting the conditions of article 33 of the 2009/31 EC directive for the planned Ptolemaida-5 unit.

Apart from the strict interpretation of the conditions set in the Directive, the most important among those being the MEECC approval of the storage location, the PPC has also made a number of violations of the procedure: it hasn't made any effort to inform and engage the public, as is essential in investments of such a scale, it hasn't obtained right of way for the suggested route and it hasn't ensured the compatibility of constructing the pipe within potentially protected areas in its route.

APPENDIX D

Local authorities of Western Macedonia on the construction of the unit

Below are presented a number of decisions taken by the Local Authorities of the wider region of Ptolemaida, related to the Environmental Impact Assessments of the mines and the proposed units:

- In January 2009, the municipal council of Dim. Ipsilantis[114] and the regional unit council of Kozani[115] expressed their opposition towards the new JMD (Joint Ministerial Decision) amending the 114804/3671/23.10.03 JMD “Approval of environmental provisions for the exploitation of the 110,889 m^2 “PTOLEMAIDA” lignite mine of the PPC SA, located in the Kozani region”, with which the PPC proceeds with expanding the mines without any provisions for the relocation of the Pontokomi and Mavropigi settlements.
- In February 2011, the EIA of the Ptolemaida mines was sent to the Kozani Regional Council and in reply the Municipal Councils of the region and the Regional Council stated the following:
    - On 24/3/2010 the Dim. Ipsilantis Municipal Council simply commented on the study[116]
    - On 24/3/2010 the Ptolemaida Municipal Council expressed a negative opinion on the EIA[117]
    - On 26/3/2010 the Kozani Regional Council expressed a unanimous negative opinion[118]
- In June 2010 the updated EIA of the Ptolemaida mines[119] was sent to the Kozani RC and the following statements were made:
    - On 14/7/2010, with the 336/2010 decision, the Eordea Municipal Council expressed a negative opinion[120]
    - On 9/7/2010, with the 73/2010 decision, the Agia Paraskevi Municipal Council simply commented on the study
    - With the 91/2010 decision, the Ellispontos Municipal Council expressed e negative opinion on the study
    - On 15/7/2010 the Kozani Regional Council expressed an unanimous negative opinion on the EIA[121]
- Nevertheless, on 9/11/2011, the MEECC decided to approve the Environmental Terms for the exploiting the lignite reserves, in a total area of 147,925,860 m^2 [122], including the Pontokomi and Mavropigi settlements relocation.
- On 20/1/2012 the Western Macedonia Regional Council expressed a positive opinion on the EIA of Ptolemaida-5.

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114 Special Municipality Meeting of the Dimitrios Ipsilantis Municipality (25.01.09)
115 Kozani Regional Council Decision on the Ptolemaida lignite mine
116 Dimitrios Ipsilantis Municipal Council decision
117 Ptolemaida Municipal Council decision
118 Kozani Regional Council decision on the PPC mines extension EIA
119 Kozani Region Ptolemaida mines EIA
120 Ptolemaida Municipal Council decision
121 Kozani Municipal Council Decision on the Ptolemaida mines EIA
122 MEECC Approval decision on the Kozani Region Ptolemaida mines

- On 23/3/2012 the MEECC approved the environmental terms for the Ahlada mines in Florina, despite the two negative decisions of the Western Macedonia Regional Council on 31/20/2011 and 9/2/2012. On 9/5/2012 the Economic Commission of the Western Macedonia Region decided to go against the Export Credit Insurance Organization (ECIO) at the Supreme Administrative Court.[123]
- On 20/4/2012 the Regional Council issued a resolution with which it expresses its opposition towards the projected sale of the lignite mines. At the same time, following a Head of the Region proposal, it demands the exclusion of the Western Macedonia region from carbon emissions for the following 15 years, so that a dispersal effect results for the community.
- On 1/3/2013 the Kozani Municipal Council decided to issue a resolution according to which: "*It considers the Ptolemaida-5 construction project of national importance, which ensures the energy independence and autonomy of the country and contributes greatly to Regional Development. It declares that the delay of such an important developmental investment for our region is totally acceptable…*"[124].

[123] 09-05-2012, 17th Meeting of the Financial Committee of the Western Macedonia Region
[124] Kozani Municipal Council decision on the construction of the Ptolemaida 5 unit

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