

THE PROSPECT OF USING GREEK LIGNITE IN AN ENERGY PORTFOLIO RELATED TO POWER GENERATION

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Abstract

The lignite-based power generation contributes 38% towards Greece's energy independence. Reducing the lignite use while simultaneously importing more expensive natural gas both government deficit and the cost of energy will increase. This surcharge is passed to consumers. Switching to renewable resources invokes an even greater fiscal imbalance, since the costs from the use of wind turbines and solar photovoltaic panels are 87 €/MWh, and 180–284 €/MWh respectively, while natural gas stands at 95 €/MWh and lignite-derived energy is 45 €/MWh.

In case of replacing a 300 MW lignite fed power unit with a 300 MW natural gas fed power unit, the loss in income will be 66,540,000 €/year. Coupled with the increased cost of natural gas (31,800,000 €/year) the total is 98,340,000 €/year in addition to the loss of 1235 jobs.

Greek authorities intends to replace lignite-fired plants having a total installed capacity of 2531 MW with equivalent natural gas-fired plants resulting in annual total deficit in excess of 787 M€. The targets set by the Greek Ministry of Energy and Climatic Changes to reduce emissions include halving Greek lignite-derived power output from 4800 MW to 2300 MW (>-52%). This move simultaneously increases Greek energy dependence on expensive foreign energy sources and will potentially provoke social unrest at the loss of 12500 jobs with loss of annual income on the order of 670 M€. However, if the existing power output from lignite-fed power plants is maintained, the penalty that PPC (Public Power Corporation) has to pay for the resultant CO₂ emissions is significantly smaller (300 M€ at 7.5 €/t of emitted CO₂/GWh).

Proceeding with the immediate reduction in lignite-fired energy results in economic and social catastrophe (annual income loss:-670 million € + annual CO₂ emissions penalty: 348 M€= -322 M€). Lignite-fired plants will become obsolete only when the CO₂ emissions penalty exceeds 63.5 €/t of emitted CO₂/GWh from a purely economic perspective.

Key words: Power units, CO₂, Natural gas.

Περίληψη

Ο λιγνίτης συμβάλλει στη μείωση της ενεργειακής εξάρτησης της Ελλάδας κατά 38%. Η μείωση της συμμετοχής του λιγνίτη στο ενεργειακό ισοζύγιο της χώρας προκαλεί αύξηση του κρατικού ελλείμματος λόγω εισαγωγής πανάκριβων ενεργειακών πρώτων υλών και βέβαια αύξηση του κόστους της κιλοβατώρας με μεγάλες επιβαρύνσεις στους καταναλωτές και στις επιχειρήσεις. Στο ίδιο αποτέλεσμα οδηγεί και η χρήση των ΑΠΕ διότι σήμερα το κόστος της παραγόμενης ενέργειας από τους αιολικούς σταθμούς είναι 87 €/MWh και από τους ηλιακούς 180-284 €/MWh έναντι των 95 €/MWh από αυτούς του φυσικού αερίου και 45 €/MWh από τους λιγνιτικούς.

Υπολογίζοντας τις απώλειες από την αντικατάσταση μιας λιγνιτικής μονάδας των 300 MW με μία μονάδα της ίδιας ισχύος, που θα λειτουργεί με φυσικό αέριο, θα υπάρξει απώλεια εισοδήματος 66.540.000 €/έτος στην οποία αν προστεθεί το κόστος αγοράς φυσικού αερίου, που είναι 31.800.000 €/έτος, θα ανέλθει σε 98.340.000 €/έτος και απώλεια 1235 θέσεων εργασίας.

Η προβλεπόμενη, όμως από το σενάριο επίτευξης στόχων αντιμετώπισης κλιματικής αλλαγής, μείωση της εγκατεστημένης ισχύος των λιγνιτικών μονάδων της τάξης του 52% (από 4800 MW σε 2300 MW) οδηγεί σε αύξηση της ενεργειακής εξάρτησης της χώρας, που σήμερα είναι στο 62%. Επίσης δημιουργείται κοινωνική αναταραχή με την απώλεια 12500 θέσεων εργασίας και απώλεια εισοδήματος, κυρίως στη Δυτική Μακεδονία, της τάξης των 670 Μ€/έτος.

Αν διατηρηθεί η σημερινή ισχύς των λιγνιτικών μονάδων το κόστος/πρόστιμο των εκπομπών του CO₂ που επιβαρύνει την ΔΕΗ (7,5 €/t εκπεμπόμενου CO₂), δεν υπερβαίνει τα 300 Μ€/έτος, δεδομένο που καθιστά την αντικατάσταση των λιγνιτικών μονάδων από αυτές του φυσικού αερίου ή των ανεμογεννητριών εντελώς ασύμφορη οικονομικά (ετήσια απώλεια εισοδήματος: -670 Μ€/ετήσιο κόστος ρύπων: 348 Μ€/ = -322 Μ€/έτος) και κοινωνικά μη αποδεκτή λύση. Η ηλεκτροπαραγωγή από τις λιγνιτικές μονάδες θα γίνει αντισυμβατική και θα μπορεί να αντικατασταθεί από μονάδες ηλεκτροπαραγωγής με φυσικό αέριο εφ' όσον το πρόστιμο για τις εκπομπές υπερβεί τα 63,5 €/t εκπεμπόμενου CO₂.

Λέξεις κλειδιά: Μονάδες ηλεκτροπαραγωγής, CO₂, Φυσικό αέριο.

1. Introduction

The use of lignite for power generation in Greece began in 1953 following the construction of the 125 MW power plants at Aliveri, Evia. To day there are 19 power units throughout Greece with a total installed capacity of 4826 MW. These units are fed with 58 Mt of lignite/year from the surrounding coal mines. The Lignite Center of Western Macedonia in Greece directly employs 7780 workers, while each job creates a further 3.28 (Technical Chamber of Greece, 2012) indirect jobs in the region for a total of 25,518 jobs.

Lignite contributes 38% to Greece's energy independence (Figure 1). Decreasing its relative importance in the energy portfolio will increase the budget deficit due to reliance on imported energy raw materials which will increase the cost of generated kWh.

Lignite feedstock represents the cheapest cost per MWh (45 €), followed by wind turbines (87 €/MWh), natural gas (95 €/MWh) and solar photovoltaic (180-284 €/MWh) (Operator of Electricity Market, 2012; Regulatory Authority for Energy, 2012). Currently, renewable resources remain a very expensive option.

Greece's lignite reserves are presented in Table 1 while the distribution of the mineable ones is shown in Figure 2.

Ενεργειακή εξάρτηση χωρών ΕΕ από εισαγωγές

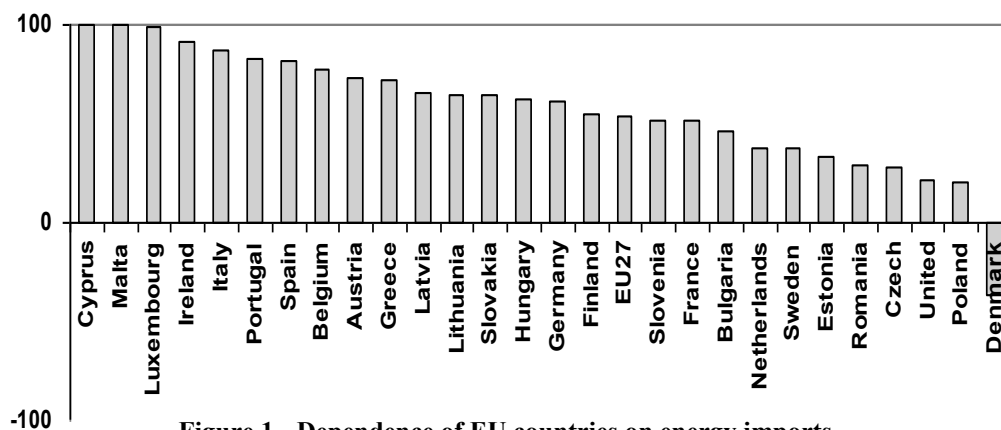


Figure 1 - Dependence of EU countries on energy imports.

Table 1 - Lignite reserves in million tonnes.

A.	PROVEN	9300
	• MINEABLE	3320
	• NON MINEABLE	2850
	• PHILIPPI PEAT	1700 ⁽¹⁾
	CONSUMED SINCE 1953	1350
B.	INDICATED	1600
C.	INFERRED	2300

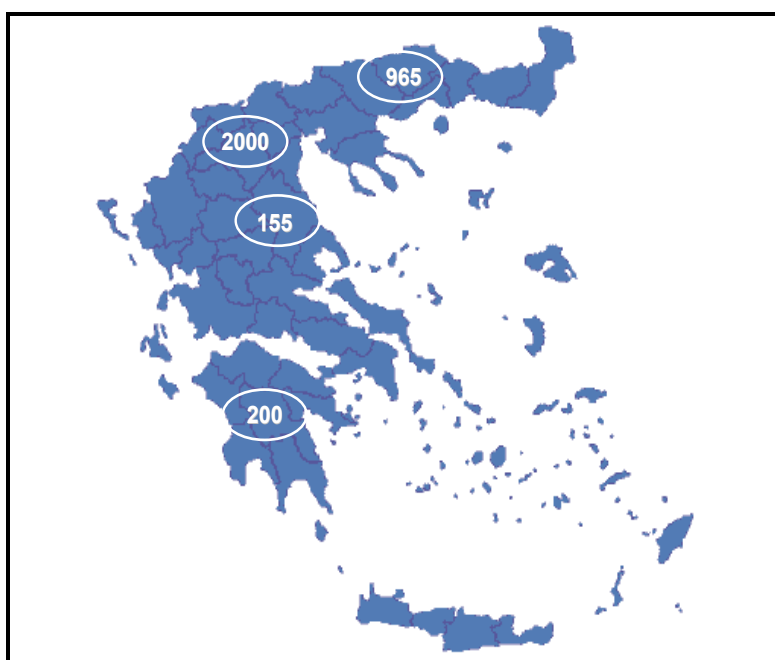


Figure 2 – The lignite deposits throughout Greece (in Mt) throughout Greece (Papanicolaou, 2001).

⁽¹⁾ 4300 Mt of peat having, equivalent calorific value to Ptolemais lignites, 1350 kcal/kg

Annual lignite production from the Lignite Center of Western Macedonia (LCWM) and the Lignite Center of Megalopolis, Peloponnese (LCMP) as well as their contribution to power generation in TWh are given in Tables 2 and 3.

The contribution of domestic lignite to the national economy should not be underestimated. Since 1960 a single area (Western Macedonia) has produced the energy equivalent of 1.15 billion barrels of oil, generating 562,000 GWh thus contributing \$49.7 billion (inflation-adjusted) to the Greek economy. It is considered that further exploitation of the remaining lignite reserves until 2054 will add to the economy \$26 billion not including the lignite reserves of Drama Basin (Philippi peat-land) and those encountered in Ellassona, Thessaly.

Table 2 - Lignite production (in kt) from the Lignite Center of Western Macedonia (LCWM) and the Lignite Center of Megalopolis, Peloponnese (LCMP) from 2006 to 2011 (Public Power Corporation of Greece S.A., 2011).

	2006	2007	2008	2009	2010	2011	2012
LCWM	49,000	49,300	40,250	50,300	43,200	47,400	52,100
LCMP	13,500	14,100	13,200	11,500	10,400	9,350	9,600
TOTAL	62,500	63,400	53,450	61,800	53,600	56,750	61,700

Table 3 - Electricity generation (in TWh) and percent contribution of each source to the energy grid in Greece (European Union, 2012).

Type/year	Units	2004	2005	2006	2007	2008	2009	2010	2011
Lignite	TWh	35.38	35.54	32.26	34.68	33.36	34.19	30.8	27.57
	%	59.6	59.2	53.1	54.6	52.35	55.7	53.66	49.5
Natural Gas	TWh	9	8.2	10.61	13.77	13.8	11.02	9.8	14.85
	%	15.20	13.60	17.45	21.70	21.65	18.00	17.07	26.70
Oil	TWh	8.4	9.2	9.6	9.6	10	7.7	6.1	4.77
	%	14.10	15.30	15.79	15.20	15.70	12.50	10.60	8.60
Hydro	TWh	5.2	5.6	6.48	3.4	4.15	5.65	7.5	3.68
	%	8.80	9.40	10.66	5.30	6.50	9.20	13.07	6.60
Renewable	TWh	1.4	1.5	1.84	2.03	2.45	2.8	3.2	4.79
	%	2.30	2.50	3.00	3.20	3.80	4.60	5.60	8.60
TOTAL	TWh	59.4	60	60.8	63.5	63.7	61.4	57.4	55.66
	%	100	100	100	100	100	100	100	100

2. The Future of Greek Lignites in an Energy Portfolio Related to Power Generation as Perceived by the Scenario to Meet Climate Change

2.1. Financial and Social Impact

The Greek government is currently attempting to respond to binding EU requirements to confront Climate Change. To this end, the Ministry of Environment, Energy and Climate Change Committee 20-20-20 on June 21, 2010 has proposed phased changes to the energy resource portfolio for the period until 2030 (Ministry of Environment, Energy and Climate Change, 2010). This initiative results from EU “Energy 2020” guidelines aimed at promoting competitive, viable and secure energy while at the same time reducing greenhouse gas emissions. The guidelines stipulate

- 20% reduction in greenhouse gas emissions below 1990 levels
- 20% reduction of the energy needs to be produced from renewable energy sources
- 20% reduction in primary energy use to be achieved by improving energy efficiency

The measures should be implemented in such a way that economic and social impacts are minimized (Ministry of Environment, Energy and Climate Change, 2010). Hence, the scenario proposed by the Greek Committee from the Ministry of Environment, Energy and Climate Change (Table 4) shows the following shortcomings.

Table 4 - Scenario for meeting the CO₂ emission targets set by the EU by 2030 (Ministry of Environment, Energy and Climate Change, 2010). Installed capacity in MW from various energy sources.

ENERGY SOURCE	2010	2015	2020	2025	2030
LIGNITE	4,826	3,992	3,363	2,295	2,295
NATURAL GAS	3,456	5,909	7,312	8,412	9,259
OIL	2,146	1,381	1,378	1,378	1,325
BIOGAS	60	120	250	370	500
HYDROELECTRIC	3,237	3,615	4,531	4,531	4,531
WIND POWER	1,327	4,303	7,500	8,750	10,000
PHOTOVOLTAIC	184	1,270	2,200	3,167	3,833
GEOTHERMAL	0	20	120	340	400
SOLAR COMB. SYSTEMS	0	30	250	380	510
TOTAL	15,236	20,640	26,903	29,623	32,653

First, instead of implementing a reduction of energy consumption by 20% between the years 2010 to 2030 the proposal aims to double the installed power capacity from 15,236 MW in 2010 to 32,653 MW by 2030. This is hard to justify in the face of far more modest increases in projected population growth and industrial output within the next 20 years. On the contrary, the last 3 years have seen the trend for increased energy demand reversed in the face of economic crisis, high unemployment, decrease in industrial output, and overseas migration of the working force. Doubling the installed power capacity is moreover contrary to EU directives for future energy management.

Secondly, the EU directive 20-20-20 proposes that from the total power capacity to be installed by 2030 over 59% (Table 4) should be derived from the renewable resources. About 30.6% will come from wind turbines, 12% from solar panels and the remaining 17.4% from hydro, geothermal and others. This not only renders the electrical grid unstable (Regulatory Authority for Energy, 2011) but also introduces energy sources which produce very expensive electricity. This high cost will be passed on to consumers

Third, using as an excuse the reduction of CO₂ emissions in order to minimize the greenhouse effect, introduces overwhelmingly the consumption of imported natural gas, 28.4%, at a delivery price of 16 \$/GJ or 12.31 €/GJ⁽²⁾ (National Natural Gas System Operator S.A., 2012) when the price of locally produced lignite is 3.5 \$/GJ or 2.7 €/GJ (Kolovos, 2010) thus creating immense social and economic problems not only in western Greek Macedonia but in the whole country.

The EU guidelines did not specify what measures should be taken to reduce the CO₂ emissions from the power plants but to reduce it in any way that Greek authorities considers appropriate. However in order to reduce CO₂ emissions by 20%, the so-called 20-20-20 Greek Committee has decided to reduce coal fired power by 50%, creating a “vital space” for the introduction of very expensive energy sources thus neglecting the colossal social and economic impact without study-

⁽²⁾ 1 € = 1.30 \$

ing alternative and less painful ways of achieving the directives set by EU. Specifically by substituting one 300MW coal fired power unit with an energy efficiency of 34% with an equivalent power unit which burns natural gas:

- Public Power Corporation S.A. of Greece (PPC) loses 31,820,000 € (annual cost of natural gas 93,170,000 € ⁽³⁾ - annual cost of 4,090,000 t of lignite X 15 €/t = 61,350,000 €) (Kolovos, 2010; National Natural Gas System Operator S.A, 2012; Technical Chamber of Greece, 2012).
- 1235 jobs are lost (each 300 MW coal fired power unit creates 1559 jobs while each 300 MW power unit which uses natural gas creates 324 jobs) (Technical Chamber of Greece, 2012).
- An annual income of 66.54 M€ is lost (Loss of 1559 jobs leads to an annual income loss of 84 M€ (Technical Chamber of Greece, 2012) while the creation of 324 jobs from the equivalent natural gas power plant yields an annual income of 17.46 M€).

Consequently, the net loss is 66.54 M€/year. Hence by decreasing the installed power of the coal fed power plants from 4828 MW, to 2295 MW (Table 4), and counterbalancing this with power plants which are fed by natural gas (equivalent of eight 300MW coal fired power units) the net financial losses incurred by the Public Power Corporation S.A. of Greece will be 254,560,000 €. This is attributed to the price difference of the feedstock being \$3.5/GJ or 2.7 €/GJ for the indigenous lignite and 16 \$/GJ or 12.31 €/GJ, for the imported natural gas. On top of it, there is a net annual income loss of 532,320,000 € (loss of Income of 66.54 €/unit of 300MW unit X 8 units = 532 M€). This means a grand total annual loss of 787 M€.

If the new natural gas fed power plants are not going to be located in Greek Western Macedonia, 12500 jobs will be lost along with an annual income loss of 670 M€.

The Committee however goes one step further by proposing the power plants fed with natural gas to reach 9259 MW, which means that, besides the existing ones of 3456 MW and the substitution of another 2531 MW lignite fired power plants by natural gas, 3272 MW natural gas fired power plants are going to be added. This means that besides the horrendous construction cost, Public Power Corporation S.A should pay for feeding the additional new 5803 MW with natural gas the exuberant price of 1.8 billion € (5803 MW X 93,170,000 € ⁽³⁾/300 MW). One wonders from where the money will come for such an undertaking when Public Power Corporation S.A (PPC) tries to reduce its dependence from natural gas. PPC used 2,400,000 kNm³, 1,700,000 kNm³ and 1,000,000 kNm³ of natural gas in 2007, 2009 and in 2011 respectively (Public Power Corporation, 2012). So the Greek Committee proposes the installation of more natural gas power plants that is complete dependence on the imported and very expensive natural gas.

Taking into account that the mean average CO₂ emissions in the last 5 years from the lignite fired plants are 40 Mt (mean price of the last five years) (United Nations Framework Convention on Climate Change, 2012) and that the penalty for it is 7.5 €/t of emitted CO₂ (September 2012), the total annual sum to be paid by the Public Power Corporation S.A. for CO₂ emissions, reaches 300 M€ (The price of allowances is 3.5 €/t CO₂ in March 2013). As a result, it is more preferable for Public Power Corporation S.A. of Greece to pay the annual penalty of 300 M€ for CO₂ emissions than assume an annual loss of 787 M€. And pay the same amount of penalty than lose 12500 jobs in Western Greek Macedonia leading to an annual income loss of income of 670 M€.

2.2. CO₂ Emissions

Based upon the guidelines of the European Committee 20-20-20 CO₂ emissions from all power plants which are 46 Mt (mean price of the last five years) (United Nations Framework Convention

⁽³⁾ Each 300 MW power unit using natural gas as feedstock and with an energy efficiency of 39% requires 7,568,640 GJ/year. Hence 7,568,640 GJ/year × € 12.31/GJ = 93,170,000 € the cost of feedstock

on Climate Change, 2012) should be reduced by 20% taking as a baseline the CO₂ emissions in 1990 which were 40 million tonnes. This implies that by 2030 CO₂ emissions should not be more than 32 Mt.

By following the scenario which is presented in Table 4, CO₂ emissions instead of being reduced to 32 Mt increase to 48.72 Mt (14800 GWh from the 2295 lignite fired power plants X 1100 t of CO₂/GWh = 16.28 Mt of CO₂ (Figure 3). Plus, 64887 GWh⁽⁴⁾ from the 9259 MW natural gas power plants X 500 t of CO₂/GWh = 32.443 Mt. So by following the scenario indicated in Table 4, instead of having reduction of the CO₂ emissions an increase is got by 52% from the Directive's target. Furthermore, the operation of lignite fired power plants will become uneconomical when the penalty for CO₂ emissions will reach the tag of 63.5 €/t of emitted CO₂ (Technical Chamber of Greece, 2012). Since this price may never be reached the guidelines set up by the Greek Committee 20-20-20 of the Ministry of Energy and Climatic Changes (Table 4) should be radically revised.

2.3. Amount and Cost of Imported Natural Gas

The amount of imported natural gas for the 9259 MW power plants is huge. Each 300 MW power plants need 7500000 GJ. Therefore the 9259 MW power plants require $231,475 \times 10^6$ GJ. Since 1GJ is equal to 1000 cubic feet of natural gas then the amount of natural gas equals $231,475 \times 10^9$ ft³ or 6.55 Gm³. Today Greece imports something in the order of 3.5 Gm³. From where are we going to get the required amount of natural gas, 4.11 Gm³, for the new 5803 MW power plants ($145,075 \times 10^6$ GJ = $145,075 \times 10^9$ cubic feet of natural gas /35.315 cubic feet of natural gas/m³ = 4.11 Gm³ of natural gas). The annual cost of importing $231,475 \times 10^6$ GJ is calculated on the basis of \$ 16/GJ. This totals 3.7 billion \$ or 2.85 billion €. And the annual penalty for the CO₂ emissions will increase from the to days 348 M€ ($46,400,500$ t of emitted CO₂ X 7.5 €/t of emitted CO₂/GWh = 348 M€) to 366 M€.

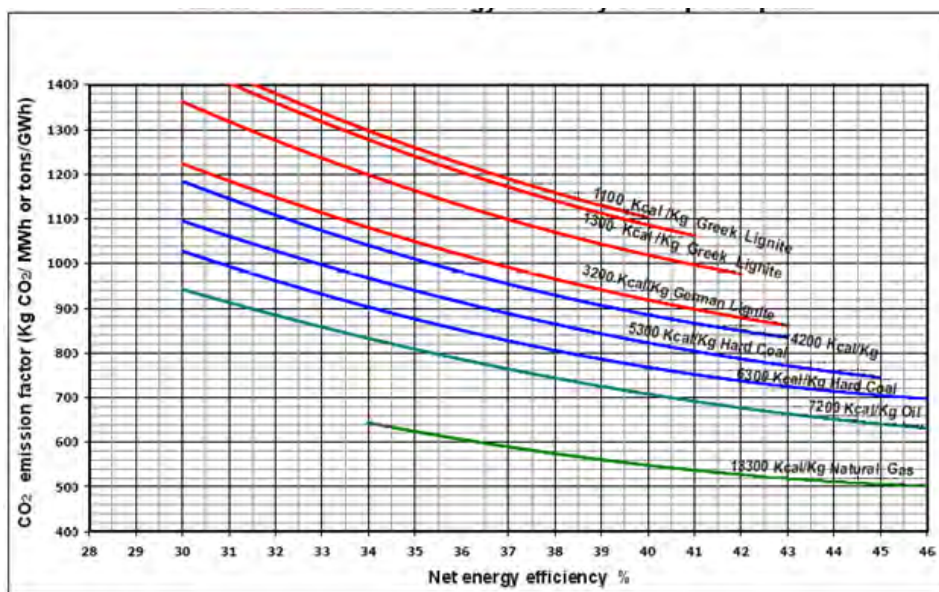


Figure 3 - Correlation of CO₂ emissions (kg CO₂/MWh or t/GWh) with the type of coal and hydrocarbon burnt its lower calorific value and the energy efficiency of the power plant (Technical Chamber of Greece, 2012).

⁽⁴⁾ Each 300MW unit which is fed with natural gas and with an energy efficiency of 39% produces, annually, 2,102.4 GWh. Hence the 9259 MW power stations will produce $9259 \text{ MW} \times 2,102.4 \text{ GWh} / 300 \text{ MW} = 64,887.072 \text{ GWh}$

Hence, the efforts of the Greek government to respond to the binding requirements to confront the Climatic Changes, Ministry of Environment, Energy and Climate Change Committee 20-20-20 in June 21, 2010 by advancing the energy portfolio which appears on Table 4 should be radically revised otherwise we will be facing a social unrest, especially in Western Macedonia, Greece will totally lose its energy independence since the country will rely exclusively on imported energy sources, Public Power Corporation of Greece S.A. will go bankrupt, the power grid will become totally unstable due to the excessive introduction of wind turbines while the price of electricity will skyrocket.

In order to conform to the European 20-20-20 guidelines the following are proposed:

- Reduction of energy consumption from 60340 GWh which is the mean average of the last 5 years (Table 3) to 48272 GWh.
- 55% of the 48272 GWh will be derived from newly constructed lignite fed power plants having an energy efficiency of 40%. The amount of CO₂ emitted will be 29.21 Mt/year (26550 GWh X 1100 t CO₂/GWh).
- 30% of the 48272 GWh, which is 14483 GWh will be derived from renewable resources. Particularly, 15% will be the contribution from wind turbines having an installed power of 4000 MW and 15% from the hydroelectric power with an installed capacity of 2600 MW while CO₂ emissions will be zero.
- 15% of the 48272 GWh that is 7241 GWh will be derived from natural gas power plants with an installed capacity of 3000 MW and energy efficiency of 43% to 44% thus emitting 3.69 Mt of CO₂/year (7241GWh X 510 t CO₂/GWh).

3. Conclusions

In the present work a detailed study of the future energy portfolio, which is related to power generation as perceived by the Greek Committee 20-20-20, set up by the Ministry of Energy and Climatic Changes, for meeting the climatic changes, is examined in relation to the European 20-20-20 guidelines which stipulates reduction of power consumption by 20%, reduction of CO₂ emissions from power plants by 20% and power production by renewable resources 20%. Unfortunately the goals suggested by the European guidelines were not implemented and the necessity of revision is imperative. Specifically,

- It doubles, unjustifiably, the installed capacity for power generation from 15236 MW to 32653 MW contrary to the EU recommendations which stipulates 20% reduction.
- Introduces into the power system more than 60% the renewable resources. Over 42 % is the contribution from wind turbines and photovoltaic systems and the remaining 17.4% from hydro and geothermal that renders the electrical grid unstable and introduces energy sources for power generation which produce very expensive electricity, >87 €/MWh for wind turbines and 180 €/MWh to 284 €/MWh for solar panels versus 45 €/MWh from lignites
- Presupposes the import of additional 4.11 Gm³ of natural gas to feed the new 5803 MW power plants at an annual cost of 2.32 billion \$ or 1.78 billion €. Today Greece imports 3.5 Gm³ of natural gas.
- Imposes on Public Power Corporation of Greece S.A. to buy expensive natural gas at a price of 16 \$/GJ (12.31 €/GJ) thus spending annually 3.7 billion \$ or 2.85 billion €.
- Increases CO₂ emissions to 48.72 Mt/year instead of reducing it to 32 Mt as required by the EU guidelines. Thus promoting a 52% increase of CO₂ emissions.
- Promotes an annual income loss of 670 M€ derived from the laying off of 12500 jobs in western Greek Macedonia thus creating a social unrest something that the European guidelines do not stipulate.

In order to conform to the European 20-20-20 guidelines the following are proposed:

- Reduction of energy consumption from 60340 GWh which is the mean average of the last 5 years to 48272 GWh.
- 55% of the 48272 GWh will be derived from newly constructed lignite fed power plants having an energy efficiency of 40%. The amount of CO₂ emitted will be 29.21 Mt/year (26550 GWh X 1100 t CO₂/GWh).
- 30% of the 48272 GWh that is 14483 GWh will be derived from renewable resources. 15% will be the contribution from wind turbines having an installed power of 4000 MW and 15% from the hydroelectric power with an installed capacity of 2600 MW. CO₂ emissions will be zero.
- 15% of the 48272 GWh that is 7241 GWh will be derived from natural gas power plants with an installed capacity of 3000 MW and energy efficiency of 43% to 44% thus emitting 3.69 Mt of CO₂/year (7241 GWh X 510 t CO₂/GWh)

Thus following to a large extend the guidelines 20-20-20 of the European Union, energy consumption is reduced by 20%, renewable resources have a share in power generation of over 20% and CO₂ emissions are reduced almost by 20%.

The net result is minimal social and economic impact in Western Greek Macedonia, stable power grid, large energy independence from imported energy sources such as natural gas and huge annual financial savings for Public Power Corporation of Greece S.A. in the order of 3 billion €.

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