The Impact of EPA's New Proposed Limits on the U.S. Power Industry

Tawfiq M. Aljohani
Ming Hsieh Department of Electrical Engineering, University of Southern California, Los Angeles, California, USA
Email: Aljohani@usc.edu

***Abstract*—The demand on electric energy has greatly increased in the recent decades. Along with the modernization and industrialization that was enabled by electric power, concerns have been raised about the detrimental impacts of the toxic gases emitted by the power plants. The Environmental Protection Agency, in conjunction with recent official U.S. plans on climate change, has proposed new standards limits on the new planned coal and natural gas-fired power plants. If passed, this standard must be met in order for the plant to be licensed and go online to the grid. The work in this article is to analyze the motivation and impact of this proposed standard on the U.S. energy scenario. The current fossil fuel technologies have been investigated to determine which type of generation technology would need further improvements to meet the newly proposed regulation. Also, a discussion on the potential influence on the energy prices is also included based on the current energy trends.**

***Index Terms*—environmental protection agency new standard limits, the future of energy, cap-and-trade market, carbon capture and storage, the energy prices, new coal-fired power plants**

I. Introduction

There is no doubt that electricity is the backbone of our modern development. The demand for power has risen exponentially in recent decades to accommodate the growing needs all over the world by the mankind. The main problem is that power generation is a major source of several air pollutants such as carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO, N_2O), carbon monoxide (CO) ...etc. This can attributed to the great dependence on fossil fuel to generate power. Specifically, the adoption of coal-fired power plants are more than those of oil or natural gas based power plants, due to the fact that there are great abundance of coal distributed throughout the world which contribute to its low price and ease of access. Yet, the coal-fired power plants have higher emissions than any other power generation technology found today with an average emission of 2,250 lbs/MWh of CO_2, 13 lbs/MWh of SO_2 and 6 lbs/MWh of NO, which are extremely high compared with those emitted by natural gas-based power plants (1,135 lbs/MWh of CO_2, 0.1 lbs/MWh of SO_2 and 1.7 lbs/MWh of NO) [1]. As a result, recent efforts have been made by the Environmental Protection Agency (EPA) in order to regulate and reduce the emissions of the released toxic gases. Among its rules and regulations, EPA has proposed in September 2013 new Clean Air Act standards in order to cut carbon pollution from the newly planned power plants which comes in conjunction with the U.S. administration's climate change plan. The new standard has been proposed to limit the new large natural gas-fired power plant CO_2 emission below of 1,000 lbs/MWh, with 1,100 lbs/MWh for the new small natural gas units. It also targets to limit CO_2 emission in the new coal-fired power plant to be below of 1,100 lbs/MWh [2].

In this work, I analyze the potential effects of this newly proposed standards-act on the power plants in the United States. I will measure which plant would survive this standard and which would not, based on the current situation for each one today, and make conclusion based on the results on the future of coal-fired power plant. To better understand EPA's motivation, I will go through the concept of the cap-and-trade of CO_2 and provide discussion on whether such program is an economic option or not. A further discussion on the energy prices will be included in this work as well to understand the effect of implementing such standards on the electric utilities.

II. Literature Review

Cap-and-trade, known also as emission or carbon trading, is a mechanism that is implemented in the power industry to reduce the greenhouse gas emissions. The main idea is to create a market where GHG allowances can be traded among utilities, where the power utilities can sell their unused portion of their limit to other utilities that did not achieve this limit and are struggling to do that. The carbon market was greatly influenced by the Kyoto Protocol, an international treaty signed by different western countries in an effort to mainly control the carbon emission. The effect of Kyoto Protocol has helped in incorporating the European Trading Scheme (ETS) as compliance tools which measuring which member of the European Union (EU) met its obligated requirement [3]. However and even though it has helped in creating the Protocol, the U.S. administration did not ratify the treaty and believed that it is flawed and can cause serious economic havoc and would be a bad deal for the U.S. in general [4], [5]. However, reference [5] based his opinion on a suggestion that Kyoto Protocol is

Manuscript received August 13, 2014; revised December 12, 2014.

doi: 10.12720/ijoee.2.4.343-347

a failed policy that would record no environmental achievement in reducing the carbon emission, which is too early to call since there are several economic and scientific studies that are currently being conducted to evaluate the protocol's real outcomes.

There were numerous efforts, supported by the EPA, to establish an American cap-and-trade program similar to that one in EU. The American Clean Energy and Security ACT (ACES) proposed in 2009 a carbon-market program where limits (caps) will be applied on carbon emission and then traded based on requirements and policies regulated by EPA. The bill was approved by the U.S. House of Representative but eventually denied in the senate [6]. Regardless of this bill, California has established its own enforceable cap-and-trade market that took effective in January 2013 with a goal to reduce 80% of the emission from 1990 level by the year 2050, and there are efforts to joint together with several Canadian provinces to create a horizontal trade program for further economic benefits [7]. According to the International Monetary Fund (IMF) a cap-and-trade program is as much efficient as the carbon taxation, which is currently used in many U.S. states. Furthermore, they suggest that cap-and-trade generates the same revenue for the government, represented by the EPA which monitor sale auctions for permits, that is equal to the allowable amount of emitted carbon by each utility, which returns somehow in benefit to the overall economy [8]. However, a survey conducted by Yale Environment 360 shows different opinions of interested environmentalists. It is suggested that the cap-and-trade program might lead to more carbon reductions than by implementing carbon taxation, but it might also cost the American household more money [9]. As this survey shows, there is great dispute on which approach could be more effective, both from environmental and economic point of view. However, I suggest in this article that the EPA is proponent to the incorporation of a cap-and-trade scenario in the American Power Industry, as it can be clearly concluded from its proposed new limits on carbon emission.

III. The Impact of the New Limits on the American Power Industry

To examine the effect of EPA's newly proposed standards, I analyze the potential effects by studying the carbon content of the fuel for each major type of conventional power plants. According to reference [10] the carbon content of both the natural gas and the sub-bituminous coal (which mostly used for power generation in the U.S) are 117.1 and 212.7 lbs/MBTU respectively. Heat rates values utilized in this work for famous generation technologies found today was taken from reference [11].

Conventional Natural Gas Combined Cycle:
117.1 lbs/MBTU x 7.05 MBTU/MWh = 825.555 lbs/MWh

Conventional Combustion Turbine:
117.1 lbs/MBTU x 10.85 MBTU/MWh = 1,270.535 lbs/MWh

Advanced Combustion Turbine:
117.1 lbs/MBTU x 9.75 MBTU/MWh = 1,141.7 lbs/MWh

Advanced Pulverized Coal Plant:
212.7 lbs/MBTU x 8.8 MBTU/MWh = 1,871.7 lbs/MWh

Supercritical Pulverized Coal Plant:
212.7 lbs/MBTU x 8.2 MBTU/MWh = 1,744 lbs/MWh

Ultra-critical Pulverized Coal Plant:
212.7 lbs/MBTU x 6.2 MBTU/MWh = 1,318.7 lbs/MWh

IV. Discussion on the Results

Based on the calculation, it is noticeable that some of the existing power plants, although have advanced technologies, will not survive the new standard requested by EPA. For instance, it is clear that the conventional NGCC will survive the limit, where in a regular basis, the emission rates have a comfortable margin from that one proposed by EPA, which is 1,000 lbs/MWh. Thus, we can say that this type of power plants is on a safe side and can be implemented in the future without requiring any major modifications. However, this is not the case for the combustion turbines (CTs). CTs have different sizes which yield several heat rates based on the size and ratings. Therefore, we suggest that there would be some CTs type that could barely survive EPA's new limit, while some of them, such as the conventional CTs, would require further enhancements in order to satisfy the new requirements. Table I shows the different specifications (including the heat rates) for several advanced CT technologies currently available in the industry [12]. Noticeably, we can draw conclusion from the above calculations that there is no way the pulverized coal plant, even the most advanced type, the ultra-critical coal plant, could survive the new limit, set at 1,100 lbs/MWh. This indicates an important note: either there would be no more coal power plants to be considered in the future, or to ensure that if built, it must be equipped with a very developed carbon capture technology, which also facilitate the way to initiate a cap-and-trade carbon market in the U.S. similar to that one made for SO_2.

The overnight cost (which is the constructing cost of the power plant without incurring interest rate during the construction) would definitely increase when considering the CCS technology. Table II shows the projected costs of the new coal-fired power plants with and without CCS technology [13]. It is clear that the energy prices will be affected by the implementation of such system. Testifying before the house energy committee, Dr. Julio Fridmann, the deputy assistant secretary for clean coal at DOE, suggested that energy prices will inevitably witness increase between 70 to 80% of the current values, in case the U.S. proceeds to mandate the CCS technology [14], [15].

TABLE I. AVAILABLE CT TECHNOLOGIES NOWADAYS

Generator Drive (ISO conditions - natural gas - electrical generator terminals)

	ISO RATED POWER kW	HEAT RATE kJ/kWh	EFFIC. %	PRESSURE RATIO	EXHAUST FLOW kg/sec	EXHAUST FLOW lbs/sec	TURBINE SPEED RPM	EXHAUST TEMPERATURE °C	EXHAUST TEMPERATURE °F
GE10-1	11,250	11,489	31.4	15.5	47.5	104.7	11,000	482	900
PGT16	13,720	10,295	35.0	20.2	47.3	104.3	7,900	491	919
PGT20	17,464	10,238	35.2	15.7	62.5	137.7	6,500	475	887
PGT25	22,417	9,919	36.3	17.9	68.9	151.9	6,500	525	976
PGT25+	30,226	9,084	39.6	21.5	84.3	185.9	6,100	500	931
PGT25+G4	33,057	9,047	40.0	23.2	89.6	197.7	6,100	510	950
LM6000*	42,262	8,787	41.1	28.0	125.0	275.0	3,600	455	851
LMS100*	98,196	7,997	45.0	40.0	206.9	456.0	3,600	417	782
MS5001	26,830	12,687	28.4	10.5	125.2	276.1	5,094	483	901
MS5002E*	31,100	10,285	35.0	17.0	102.0	225.0	5,714	511	952
MS6001B	42,100	11,230	32.1	12.2	141.1	311.0	5,163	548	1,026
MS7001EA	85,400	10,990	32.7	12.6	292.0	643.0	3,600	537	998
MS9001E	126,100	10,650	33.8	12.6	418.0	921.0	3,000	543	1,009

(*) DLE Combustion

TABLE II. TOTAL PLANT AND LCOE OF NEW COAL-FIRED POWER PLANT WITH AND WITHOUT CCS TECHNOLOGY

(2010 dollars)

	Total Plant Construction Costs[a]		Levelized Cost of Electricity[b]	
	Supercritical Pulverized Coal Plants[c]	Subcritical Pulverized Coal Plants[c]	Supercritical Pulverized Coal Plants[c]	Subcritical Pulverized Coal Plants[c]
Carnegie Mellon University				
Without CCS	1,788	1,710	55.9	56.0
With CCS	3,237	3,234	97.3	100.8
Premium for CCS (Percent)	81	89	74	80
Electric Power Research Institute				
Without CCS	1,888	[d]	65.5	[d]
With CCS	3,138	[d]	111.5	[d]
Premium for CCS (Percent)	66	[d]	70	[d]
Global Carbon Capture and Storage Institute				
Without CCS	1,919	[d]	57.4	[d]
With CCS	3,464	[d]	101.8	[d]
Premium for CCS (Percent)	81	[d]	77	[d]
Massachusetts Institute of Technology				
Without CCS	1,734	1,669	53.1	54.6
With CCS	2,790	2,907	95.4	103.3
Premium for CCS (Percent)	61	74	79	89
National Energy Technology Laboratory				
Without CCS	1,637	1,612	63.2	64.0
With CCS	2,895	2,924	107.7	111.3
Premium for CCS (Percent)	77	81	71	74

The levelized cost of Energy (LCOE) can be calculated for any power plant as following:

$$LCOE = \frac{TCR}{CF} + \frac{O\&M}{CF} + O\&M(variable) \quad (1)$$

where TCR is the annuity of total capital requirement (US$ year^{-1}); CF is the plant's capacity factor; O&M is the operational and maintenance (has both fixed and variable costs). To better understand the numbers mentioned in the tables, the cost of CCS can be calculated as following:

$$C_{CO2}=[LCOE_{Capture} - LCOE_{with\ no\ Capture}]/[(\frac{CO2}{EE}2 - \frac{CO2}{EE}1) \quad (2)$$

Equation (2) assesses if CCS technology is economically viable or not, where it divides the difference in LCOE for the plant before and after the installation of the scrubbers over the amount of emissions of CO_2 before (1) and after (2) the installation of scrubbers. Other important factors such as the useful life of the plant, discount rate, and capital costs is calculated via TCR mentioned in equation one [16]. As mentioned above, CCS will definitely yield in an increase in the energy cost. Yet, did the utilities have another options rather than depending on coal-fired plants?

There is another source of energy that could witness drastic changes. The nuclear energy is currently in a practical phase-out in the U.S., raising questions about the future of this powerful technology as well. For instance, it was announced in June 2013 that San Onofre nuclear power plant, located in the midway between Los Angeles and San Diego, currently offline since 2012 for maintenance purposes, will retire reactors number two and three out of three forever, after the first reactor was decommissioned in 1992. This is not the first case in California, the most populated state in the U.S., where many of their nuclear facilities had been closing and/or retiring without building new ones for substitution [17]. Another example for the shifting trend is when Duke Energy announced its intention to suspend a $24 billion nuclear power plant project in Central Florida, after the company pointed-out to uncertainties hover around recovery costs related to the project. The same company had announced earlier the retirement of one of its nuclear subsidies, the Crystal River power plant, which is located on the west coast of Florida [18]. All of the shifting policies, whether on nuclear or coal, would definitely lead to a substantial increase in the energy prices. Currently, we can see that the U.S. energy policies are heavily lay down on natural gas, considering conventional power plant, due to the recent decrease on its prices. However, the average retail bills prices of electricity have been raised up from 8.95 ₵/KWh to 12.12 ₵/KWh in the residential sector from 2004 to 2013, marking a 35.42% increase [19].

V. Conclusion

EPA's new-limit standards will definitely, if approved, be a game changer. Based on the calculation mentioned in this work, only the natural gas-fired plants would survive the new limitation, while some of the CTs will and some will not, based on how advanced the used CT is. Speaking about coal, there will be dramatic changes since all the modern types used, including the most advanced ones, will be required to install advanced carbon scrubbers or will be asked to either retire, change fuel, or forced to form a cap-and-trade market in order to survive. However, the environmentalists have doubts and concern over the cap-and-trade success in achieving the desired goals without affecting the energy prices. According to Fred Krupp, president of the Environmental Defense Fund, Obama administration has proposed that the generated revenues from cap-and-trade program should return to the American people [9]. Yet, this will guarantee nothing to the consumers who already have witnessed an increase over 34% in their energy bills in the past decade. Not to mention that there are many energy-related officials have warned that the current energy policies would lead to increase energy costs in many aspects [20].

From my point of view, I agree with the concept that EPA's new limits on the natural gas and coal-fired power plant will lead, if passed, to substantial increase on the energy prices in the upcoming years. Also, with the nuclear power being shifted away out of the industry's future, there are questions raised on how the future energy needs of the U.S. can be met? Will natural gas (which currently operates at as half as capacity factor of nuclear) be capable to take the lead and be America's number one source of energy? Are we going to witness a major shift in the renewable energy field so that there would be no more major dependence on fossil fuel in general, and on coal in specific? All of these are part of several questions that are needed to be answered in order to have a clear insight to the future of energy in this country.

Appendix Abbreviations

EPA: U.S. Environmental Protection Agency.
CO_2: Carbon Dioxide.
CO: Carbon Monoxide.
SO_2: Silver Dioxide.
N_2O: Nitrogen Oxides.
MWh: Megawatt hour.
lbs: Pounds.
BTU: British Thermal Unit.
GHG: Greenhouse Gas Emissions.
DOE: U.S. Department of Energy.
LCOE: Levelized Cost of Energy.
CCS: Carbon Capture and Storage.
NGCC: Natural Gas Combined Cycle.
CT: Combustion Turbine.
₵: U.S. Cent.
IMF: International Monetary Fund.
ACES: American Clean Energy and Security Act.
EU: the European Union.
ETS: European Trading Scheme.
TCR: Total Capital Requirement.
CF: the Capacity Factor.

Acknowledgment

I would like to express my deep gratitude to Taibah University for providing me with a scholarship to continue my higher education. I would like also to thank the University of Southern California for the decent educational environment it provides to student. Last but not least, I would like to express my deep love and thanks to my mother Maysar, wife Sarah, daughter Haifa, and all my brothers and sisters for being the best family anyone could have in this world.

REFERENCES

[1] United States Environmental Protection Agency. (2013). How does electricity affect the environment? [Online]. Available: http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

[2] J. P. Valentine. (2013). EPA proposes carbon pollution standards for new power plants. *United States Environmental Protection Agency News Room* [Online]. Available: http://yosemite.epa.gov/opa/admpress.nsf/0/da9640577ceacd9f85257beb006cb2b6!OpenDocument

[3] D. Ellerman and P. Joskow, *The European Union's Emission Trading System in Perspective*, Arlington, VA: Pew Center on Global Climate Change, 2008.

[4] D. Brown, *Climate Change Ethics: Navigating the Perfect Moral Storm*, New York, NY: Routledge, 2013, pp. 44.

[5] G. Landrith, *On Politics and Policy: Views on Freedom from an American Conservative*, Lincoln, NE: iUniverse, Inc., 2004, pp. 79.

[6] (2009). American Clean Energy and Security Act of 2009, H.R. 2454. [Online]. Available: http://www.opencongress.org/bill/111-h2454/actions_votes

[7] California Environmental Protection Agency. (2013). Cap-and-Trade program. [Online]. Available: http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

[8] International Monetary Fund. (Mar. 2008). *The Fiscal Implications of the Climate Change*. [Online]. Available: http://www.imf.org/external/np/pp/eng/2008/022208.pdf

[9] Yale Environment 360. (May 7th, 2009,). Putting a price on carbon: An emissions cap or a tax? [Online]. Available: http://e360.yale.edu/content/feature.msp?id=2148

[10] Carbon Light House Association. (2010). *Energy Units and Conversions*. [Online]. Available: http://www.carbonlighthouse.org/wpcontent/uploads/2010/10/UnitsAndConversions.pdf

[11] United States Energy Information Administration. (Apr. 2013). *Updated Capital Costs Estimates for Utility Scale Electricity Generating Plants*. [Online]. Available: http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf

[12] R. Shepard. Gas turbines technologies for electric generation. [Online]. Available: http://www.ieeems.org/Meetings/presentations/MS3ASME%20Gas%20Turbine%20Technologies%20Presentation.ppt

[13] Congress of the United States and Congressional Budget Office. (Jun. 2012). Federal efforts to reduce the cost of capturing and storing carbon dioxide. [Online]. Available: http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf

[14] United States House of Representative and Energy and Commerce Committee. (Feb. 2011). DOE official: Initial CCS technologies estimated to increase wholesale electricity costs up to "70 to 80 percent". [Online]. Available: http://energycommerce.house.gov/press-release/doe-official-initial-ccs-technologies-estimated-increase-wholesale-electricity-costs-

[15] M. Bastasch. (Feb. 11, 2014). EPA "clean coal" rule would increase power prices by 70 or 80 percent. *The Daily Caller*. [Online]. Available: http://dailycaller.com/2014/02/11/epa-clean-coal-rule-would-increase-power-prices-by-70-or-80-percent/

[16] B. S. Hoffman and A. Szklo, "Integrated gasification combined cycle and carbon capture: A risky option to mitigate CO_2 emissions of coal-fired power plants," *Applied Energy*, vol. 88. pp. 3917-3929, 2011.

[17] California Energy Commission. Nuclear plants in California. [Online]. Available: http://www.energy.ca.gov/nuclear/california.html

[18] D. Adams. (Aug. 1, 2013). Duke energy shelves major nuclear project in florida. *Reuters*. [Online]. Available: http://www.reuters.com/article/2013/08/02/utilities-duke-levyidUSL1N0G227O20130802

[19] United States Energy Information Administration. (Mar. 2014). Independent statistics and analysis. [Online]. Available: http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3

[20] Institute for Energy Research. (Jan. 2014). Senators call attention to Obama policies that increase energy costs. [Online]. Available: http://www.instituteforenergyresearch.org/2014/01/30/senators-call-attention-to-obama-policies-that-increase-energy-costs/

Tawfiq M. Aljohani received his B.SC degree in electrical engineering in 2009 from King Abdulaziz Univeristy, Jeddah, Saudi Arabia. He received his Master of Science degree from the University of Southern California, Los Angeles, CA in electric power engineering as well, where he starts his PhD degree in the same filed in Fall 2014. His research interests include determenstic and probabilistic power system planning, power system reliability, power system operation and security, renewable energy and smart grid applications.

