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Valuing Externalities of Coal Power Plants in Western Visayas using Benefit Transfer Method

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ABSTRACT

This study attempts to value the externalities generated by coal power plants in Western Visayas and determine the efficiency implications of valuing these externalities. Valuing externalities can help determine the appropriate environmental policy, such as the amount of tax that will correct for the inefficiency. Benefit Transfer Method (BTM) specifically unit value transfer, was used to estimate the values of pollution damages. To estimate the externalities of coal power in Western Visayas, this study first looked at the emissions caused by three major advanced coal power technologies: Pulverized Fuel (PF), Circulating Fluidized Bed (CFB) and Integrated Gasification Combined Cycle (IGCC). The two existing coal power plants in Western Visayas utilize CFB technology, which has a higher fuel flexibility and require a lower capital cost. After which, several studies that estimate the values of greenhouse gas (GHG) externalities were examined. These values were then applied to the emissions of the two coal power plants in the region. Results show that total externalities range from PhP 0.08/kWh to PhP 0.44/kWh. This can increase the current effective electricity rate by 0.65 to 4.1 percent.

Keywords: Coal energy, externalities, valuation, clean coal technology, corrective tax, power plants

INTRODUCTION

The abundance of coal makes it a reliable and major source of energy among fossil fuel resources (Franco & Diaz, 2009). For this reason, coupled with low prices, it will continue to be dominant in the energy sector for a long time. However, the pressure for environmental protection by lowering greenhouse gas (GHG) emissions calls for adoption of "clean coal technology" (Franco & Diaz, 2009; Chen & Xu, 2010) or a shift to other energy sources (International Energy Agency [IEA], 2017). Developing nations demand more energy at low prices, but the rising concern for damages caused by GHGs poses a challenge to the government to provide a cleaner, reliable, and cheaper energy (Franco & Diaz, 2009; International Energy Agency, 2017).

Chen and Xu (2010) show that coal is responsible for majority of GHG emissions. Considering that coal power will still be a major source of energy in the future, investment in clean coal technology has the potential to lower the harmful effects of these emissions and increase the efficiency of coal utilization. However, the adoption of clean coal technology depends on the incentives that will ease or hamper this transition. Pollutants create what economists call market externalities, where polluters do not pay the full social cost of their emissions. To curb pollution, economists advocate the correct pricing of these externalities (Mahapatra et al., 2012; Muller & Mendelsohn, 2007). These prices can also be a basis for corrective tax to address the market inefficiencies (Nicholson & Snyder, 2008).

The study focuses on two coal power plants in Western Visayas: a 164 MW coal- fired power plant in Barangay Ingore, La Paz District, Iloilo City and a 135 MW in Barangay Nipa, Concepcion, Iloilo. An additional 135 MW coal power was constructed as an extension of the Concepcion coal power (The Philippine Star, 2016) and another 150 MW in La Paz to cater to the growing demand of the region (Philippine Daily Inquirer, 2016). The two power plants are monitored by the Department of Environment and Natural Resources (DENR). There had been complaints from local residents suffering from scabies and lung problems due to alleged pollutants emitted by these two (Iloilo Metropolitan Times, 2017b).

Presently, electricity fees do not reflect the externalities caused by coal. There are also no primary studies that estimate the value of the coal externalities here in the country, since estimating the value of externalities is difficult to accomplish. However, there are several existing studies that estimate the cost of GHG emissions abroad. These values can be applied to the Philippine context using the benefit transfer method (BTM). This method was chosen to estimate the values of externalities because some of limitations. First, conducting a primary study to determine one externality (i.e. health effects) requires panel data. This kind of research requires a large amount of budget to cover the rigorous data gathering and analysis. There are still other externalities that need valuation. Second, some data (i.e. GHG emissions of power plants) are not readily available.

This paper seeks to look at the emissions of different clean coal technologies used today, the corresponding monetary value of these externalities in the case of coal power in Western Visayas, and the Pigouvian tax that can be appropriated for these externalities.

Specifically, the study aims to answer the following questions:

1. What technology do coal power plants in Western Visayas use?
2. How much are the costs of externalities?
3. How much should be the corrective tax?

The estimated value of externalities of coal power in the region can be the basis for charging the corrective tax. This can be an added fee to electricity, or an amount that can be charged the coal power operators. Since GHGs cause damages to the environment and health, the collected tax can be used as a fund to compensate for these damages.

REVIEW OF RELATED LITERATURE

This chapter is separated into three sections. The first section discusses the different technologies used in coal power, the GHGs they produce, and the amount of their emissions. The second part lists the damages caused by GHG emissions coming from coal power. The last section examines the estimated cost of these damages.

Different Technologies of Coal Power and Their Emissions

Based on the literature, major clean coal technologies are advanced pulverized fuel (PF) combustion plants, integrated gasifier combined cycle (IGCC) and circulating fluidized bed (CFB), with several variations (Franco & Diaz, 2009; Liu, et al., 2015; Zhao et al., 2010). Table 1 summarizes the studies that discuss latest technology of coal power, their corresponding pollutants, and their respective emission levels.

Davison (2007) assessed the leading technologies in capturing carbon dioxide (CO_2) in power

Table 1. Summary of Studies with Emissions from Clean Coal Technologies

Author/Year/Study	Type of Technology	GHG Pollutant	Emission Level (t/MWh)
Davison, J. 2007. Performance and costs of power plants with capture and storage of CO_2.*	Pulverized Fuel (PF)	CO_2	0.82 without capture technology; 0.093-0.129 with capture technology
		SO_x	<0.00001
		NO_x	0.0003-0.0008
	IGCC	CO_2	0.84 without capture technology; 0.157-0.168 with capture technology
		SO_x	0.00001
		NO_x	0.0004-0.0006
Lu, et al., 2008. Policy study on development and utilization of clean coal technology in PRC.	PF		
	Subcritical + FGD	SO_x	0.00026
		NO_x	0.00083
	Supercritical + FGD Ultra-	SO_x	0.00025
		NO_x	0.00081
	Supercritical + FGD	SO_x	0.00024
		NO_x	0.00078
	CFBC	SO_x	0.00026
		NO_x	0.00043
	IGCC	SO_x	0.00001
		NO_x	0.00007

Table 1 continued

Author/Year/Study	Type of Technology	GHG Pollutant	Emission Level (t/MWh)
Franco, A. and Diaz, A. 2009. The future challenges for ''clean coal technologies'': Joining efficiency increase and pollutant emission control.	PF CFB IGCC	CO_2 CO_2 CO_2	0.93-0.99 0.88-0.93 0.82-0.86
Environmental Protection Agency (EPA). 2010. Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units.	PF CFB IGCC	CO_2 CO_2 CO_2	0.93-0.97 0.11 with capture technology 0.98-1.01 0.93

*Data were in g/kWh and converted to t/MWh (1ton= 907184.74 g)
CO_2 = carbon dioxide; SO_x = sulfur oxides; NO_x = nitrogen oxides

generation plants. The study looked at performance, cost and emissions data for coal power based on the studies carried out for IEA Greenhouse Gas R&D Programme. Results reveal that PF has an emission of 0.093-0.129 t/MWh CO_2, almost zero sulfur oxides (SO_x), and 0.0003-0.0008 t/MWh nitrogen oxides (NO_x), while IGCC has an emission of 0.157-0.168 t/MWh CO_2, 0.00001 t/MWh SO_x, and 0.0004-0.0006 t/MWh NO_x. Furthermore, IGCC with pre-combustion CO_2 capture technology had the lowest cost per CO_2 avoided.

Lu, et al. (2008) discussed the different available clean coal technology, evaluated and compared their performance, and recommended policies suitable for PRC. The paper argued that the present situation in PRC prevents the complete switch to cleaner fuel such as natural gas, hence the country still must rely heavily on coal. The solution is to use clean coal technology in order to minimize the pollution caused by burning coal. Results show that PF emits 0.00024-0.00026 t/MWh SOx and 0.00078-0.00083 t/MWh NOx, CFB releases 0.00026 t/MWh SOx and 0.00043 t/MWh NOx, while IGCC produces 0.00001 t/MWh SOx and 0.00007 NOx. IGCC is found to be the most efficient in coal consumption, and the has the least SO_2 emission. On the other hand, CFB is the least costly. The authors recommend to use super (ultra-super) critical units equipped with flue gas desulfurization (FGD), supplemented with CFB is the long-term solution considering the country's energy situation and level of economic development.

Franco and Diaz (2009) emphasized the role of coal in the medium term, being an abundant and stable source of energy. The paper analyzed the emissions from different coal technologies that make coal "clean", as a solution to the increasing global demand for energy and the need for low prices to aid continuous development. Results reveal that PF has an emission of 0.93-0.99 t/MWh CO_2, CFB has an emission of 0.88-0.93 t/MWh CO_2, while IGCC emits 0.82-0.86 t/MWh CO_2. The paper pointed out that IGCC is a promising solution in the long-term in pursuing cleaner coal technology, PF is a mature technology which can employ ultrasupercritical (USC) technology in order to lower emissions, and CFB is a choice because it can increase efficiency of a power plant.

EPA (2010) reported the list of technologies used for coal power. The paper discussed the characteristics of technologies like PF, CFB, and IGCC. CFB technology is adopted at lower plant generation capacity compared to PF, but its advantage over PF is evident on its fuel flexibility, which means that it can be fed with any rank of coal without any modification. IGCC emits the lowest emissions but is also the most expensive among the three. Only CO_2 emissions of electricity generating units were presented, from subcritical to supercritical PC-fired, subcritical to supercritical CFB boiler, and IGCC coal power. Results show that except for additional carbon capture installed, the IGCC and supercritical PF technology return the lowest CO_2 emissions. PF technology emits 0.93-0.97 t/MWh of CO_2, IGCC emits 0.93 t/MWh of CO_2, while CFB emits 0.98-1.01 t/MWh of CO_2.

In summary, pulverized coal technology is often used by large power plants. It is already a mature technology. On the other hand, CFB has low capital cost and is more flexible in terms of using any rank of coal. It is not clear whether PF or CFB technology has the highest rate of emissions, but IGCC is arguably the cleanest available coal technology in the present. Unfortunately, this technology is also the most expensive. Equipping these units with super (ultra-super) critical features can lower the GHG emissions.

Damages Caused by Greenhouse Gas Emissions

Table 2 shows the damages caused by GHG emissions and the respective studies that highlighted these damages. The GHGs emitted by coal power are mainly CO_2, SOx, NOx, methane (CH_4), and particulate matter (PM).

Table 2 illustrates that GHGs CO_2, SOx, NOx, and CH_4 interact with each other to cause climate change, which includes sea level rise and other catastrophic events. These gases also cause materials corrosion, damages to properties, crops or vegetation and loss of visibility. On the other hand, PM causes loss of visibility, mortality, and morbidity such as bronchitis, pneumonia, and asthma attacks. Its effects are more felt by the local community. This indicates that GHGs inflict indirect costs to the society, and there are

Table 2. Damages of Greenhouse Gas Emissions

Greenhouse Gas	Damage	Study
Carbon Dioxide (CO_2)	Climate change (includes sea level rise, catastrophes)	US EPA (2013); Hope (2011); Mahapatra, et al. (2012); Nordhaus (2011); Tol (2008); Tol (2011); Waldhoff et al. (2014)
	Damage to agriculture/forestry/ property	US EPA (2013); Nordhaus (2011); Waldhoff et al. (2014)
	Health problems	US EPA (2013); Mahapatra, et al. (2012); Nordhaus (2011); Waldhoff et al. (2014)
Sulphur Oxides (SO_x)	Climate change (which is also responsible for the damages below)	Waldhoff et al. (2014)
	Health problems	Mendelsohn (1980)
	Combines with NOx that causes health problems	Jaramillo and Muller (2016); Levy et al. (2009)
	Materials corrosion	Mahapatra, et al. (2012); Matthews and Lave (2000); Mendelsohn (1980)
	Acid rain	Mendelsohn (1980)
	Combines with NOx to produce acid rain	Mahapatra, et al. (2012)
	Damage to crops/vegetation	Mahapatra, et al. (2012); Mendelsohn (1980)
	Loss of visibility	Mendelsohn (1980)
	Combines with NOx to cause loss of visibility	Matthews and Lave (2000)
Nitrogen Oxides (NO_x)	Climate change (which is also responsible for the damages below)	US EPA (2013); Waldhoff et al. (2014)
	Health problems	Mendelsohn (1980); Waldhoff et al. (2014)
	Combines with SOx that causes health problems	Jaramillo and Muller (2016); Levy et al. (2009); Waldhoff et al. (2014)
	Materials corrosion	Mendelsohn (1980)
	Acid rain	Mendelsohn (1980)
	Combines with SOx to produce acid rain	Mahapatra, et al. (2012)
	Damage to crops/vegetation	Mahapatra, et al. (2012); Mendelsohn (1980)
	Loss of visibility	Mendelsohn (1980)
	Combines with NOx to cause loss of visibility	Matthews and Lave (2000)
Methane (CH_4)	Climate change resulting to agriculture, forestry, sea level rise, cardiovascular and respiratory disorders	Waldhoff et al. (2014)
	Reacts with CO_2 to cause climate change damages	US EPA (2013)
Particulate Matter (PM)	Mortality, morbidity (i.e. bronchitis, pneumonia, asthma attacks, hospital admissions)	Jaramillo and Muller (2016); Levy et al. (2009); Mahapatra, et al. (2012); Matthews and Lave (2000); Mendelsohn (1980); New South Wales EPA (2013)
	Loss of visibility	Mendelsohn (1980)

studies that estimate the values of these damages.

Costs of Coal Power Emissions

Table 3 summarizes the studies that discuss the cost of emissions of coal power in different countries. Based on the literature, coal power generates GHG emissions such as CO_2, the main contributor to global warming and climate change, as well as NO_x, SO_x, CH_4, Nitrous oxide (N_2O), which is a variant of NOx, and PM that affect the environment and human health.

Several authors agreed on the importance of including externalities in order to achieve economic efficiency. Stiglitz (2006) asserted that failure to internalize negative externality imposes an automatic subsidy from the society. In the "polluter pays principle", a right amount of tax should compensate for the damage done to the environment or society. In the case of coal power, one of the biggest market failures is the failure to internalize CO_2 emission (Stern & Taylor, 2007). Heal (2008) also claimed that social costs should be part of the computation when determining the cost of energy.

Table 3. Damages of Greenhouse Gas Emissions

Author/Year/Study	**Study Data**	**Method Used**	**Results**
Mendelsohn, R. (1980). An Economic Analysis of Air Pollution from Coal-Fired Power Plants.	USA 500MW	CBA, Abatement method using environmental model divided into 4 submodels: abatement engineering, atmospheric transport, victim exposures, and dose responses.	Externalities of uncontrolled coal-fire power plant using abatement: • Sulfur abatement - $36.7 million • Particulate abatement - $26 million • Nitrogen abatement - $7.2 million • Other abatement cost - $0.11 million Estimated marginal damages: • acid rain, materials, and vegetation damages: $1.5 million • visibility losses: $1 to 8 million • health loss: $4 to $40 million
Matthews, S., and Lave, L. (2000). Applications of Environmental Valuation Determining Externality Costs.	8 studies	Review of related literature on economic analysis of externality costs	Social Damage Estimates ($1992) from Air Emissions: • CO - $520/t • NO_x - $2,800/t • SO_2 - $2,000/t • PM_{10} - $4,300/t
Mahapatra, et al. (2012). External cost of coal-based electricity generation: A tale of Ahmedabad city	India, 870 MW and 400MW coal power plants	Life Cycle Analysis (LCA) 2 main methods: 1) calculation of damage costs 2) calculation of abatement costs	Damage costs: • human health - 39.7 paisa/kWh ($7.44/MWh) • building materials – 4.1 paisa/kWh ($0.77/MWh) • agricultural crops – 3.3 paisa/kWh ($0.62/MWh) • carbon emission -141 paisa/kWh ($26.42/MWh)
Waldhoff, S., et al. (2014). The Marginal Damage Costs of Different Greenhouse Gases: An Application of FUND	16 regions of the world	Framework for Uncertainty, Negotiation and Distribution (FUND)	Social cost of GHGs in 2007: • $9.1/t CO_2 • $431.9/t CH_4 • $6,016/t N_2O
Levy, J. et al. (2009). Uncertainty and Variability in Health-Related Damages from Coal-Fired Power Plants in the United States	407 coal-fired power plants in the United States	Source-Receptor (SR) Matrix, a reduced-form chemistry-transport model accounting	Damages across plants: • $30,000 to $500,000/t $PM_{2.5}$ • $6,000 to $50,000/t SO_2 • $500 to $15,000/t NO_x • A total of $0.02 to $1.57 per kilowatt- hour of electricity generated

Table 3 continued

Author/Year/Study	Study Data	Method Used	Results
Jaramillo, P. and Muller,N. (2016). Air pollution emissions and damages from energy production in the U.S.: 2002–2011	air pollution emissions data for the years 2002, 2005, 2008, and 2011	AP2, an integrated assessment model to estimate the external cost associated with air pollution emissions from industries that extract fuels for energy use	2002 marginal damage: • \$14,000/t SO_2 • \$2,400/t NO_x \$26,000/t $PM_{2.5}$
Tol, R. (2008). The Social Cost of Carbon:Trends, Outliers and Catastrophes	211 estimates	Meta-analysis	SCC estimates: European Union (2008) - \$160/tC (\$43.6/tCO_2)
US EPA (2013). The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions			Social Costs of GHGs: • \$37/tonne CO_2 (\$36.26/tCO_2) • \$1,000/tonne CH_4 (\$907.18/tCH_4) \$13,000/tonne N_2O (\$11,793.40/tN_2O)
Hope, C. (2011). The Social Cost of CO_2 from the PAGE09 Model.		PAGE09 Model	Social Cost of Carbon: \$50-\$100/tCO_2
Tol, R. (2011). The Social Cost of Carbon.	13 studies	Literature survey	Social Cost of Carbon: \$59/tC or \$16/tCO_2
Nordhaus, W. (2011). Estimates of the Social Cost of Carbon: Background and Results from the RICE-2011 Model.	12 regions in the world	RICE-2011 model	Social Cost of Carbon: \$12/tCO_2
NSW EPA (2013). Methodology for Valuing the Health Impacts Of Changes in Particle Emissions – Final Report.	12 Australian Studies applied to Significant Urban Areas (SUA)	Various damage cost methods such as simplified impact pathway approach or benefit transfer from abroad	Average Social Cost in 2011 prices - AUD 63,786/tonne $PM_{2.5}$ (57,866/t$PM_{2.5}$)

Notes: $ values are in USD
1 tonne = 1.1ton
C = carbon
CO = carbon monoxide
CO_2 = carbon dioxide
CH_4 = methane
NOx = nitrogen oxides
SO_2 = sulfur dioxide
PM_{10} = particulate matter 10 micrometers or less in diameter
N_2O = nitrous oxide
$PM_{2.5}$ = particulate matter 2.5 micrometers or less in diameter

Mendelsohn (1980) determined the impact of an uncontrolled coal-fire power to the environment and society. The study was an economic analysis which analyzed how much abatement cost was needed to reduce the marginal damage of externalities. Results show that when the emissions are reduced so that environmental and societal damages are prevented, the annual abatement for sulfur would be $36.7 million, particulate about $26 million, nitrogen reached $7.2 million and other abatement cost for $0.11 million. On the other hand, the damages caused by uncontrolled coal-fired power plant include acid rain, materials, and vegetation with a total damage of $1.5 million. Visibility losses amount between $1 and 8 million annually, depending on how people value the visibility loss. Finally, the most significant of the externalities is the health loss which amounts to $4 to $40 million per year. The annual damage from uncontrolled coal-fire power then totals $7 and $50 million.

Matthews and Lave (2000) looked at different literature that use cost and benefit analysis to analyze the different environmental externalities. Eight studies in the 1990s were checked and the social damage from air emissions summarized. The paper mentioned the effects of these GHGs such as SOx causing corrosion to materials, a combination of SOx and NOx causing loss of visibility, and particulate matters that cause health problems like asthma, bronchitis, loss of work and premature mortality. It reported the mean values of externalities as: $520/t of carbon monoxide (CO), $2,800/t of NOx, $2,000/t of sulfur dioxide (SO_2) and $4,300/t of particulate matter 10 micrometers or less in diameter (PM_{10}). The values were expressed in 1992 US dollars. At this point, the use of economic valuation was still controversial. However, the authors emphasized that the results can still assist in the environmental policy.

Mahapatra et al. (2012) studied the externality of coal-based electricity generation in Ahmedabad City, India. The paper focused on two coal power in the city, with generation of 870 MW and 400MW. Life Cycle Analysis (LCA) was used in the study, using dose-response functions to estimate the damage to human health, crops and building materials. The paper pointed out that greenhouse gases have different specific effects. It attributed the cause of climate change and effects of human health on CO_2 emissions. In the same way, SOx also causes damage in materials while the combination of SOx and NOx forms acid rain that damages agricultural crops. Particulate matters have major effects on health. They cause premature mortality and morbidity effects like asthma, bronchitis, hospital admissions, and emergency visitations which further lead to loss of work. The study monetized the cost of these externalities and estimated that that cost to human health amounts to 39.7 paisa/kWh ($7.44/MWh), the cost to building materials is 4.1 paisa/kWh ($0.77/MWh) and cost to agricultural crops amounts to 3.3 paisa/kWh ($0.62/MWh) and carbon emission costs 141.3 paisa/kWh ($26.42/MWh).

Waldhoff et al. (2014) used Framework for Uncertainty, Negotiation and Distribution (FUND) model version 3.9 to determine the social cost of CO_2, methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride. FUND is an integrated assessment model "used to study cost-effective, efficient, feasible and equitable climate policy." The model used 16 major regions of the world. The paper estimated the marginal damage of CO_2, CH_4 and N_2O in 2007. It estimated the individual costs of these gases and concluded that the social cost of CO_2 is $9.1/t, CH_4 is $431.9/t and N_2O is $6,016/t.

Levy, et al. (2009) studied the degree of variability and contributing factors of plant, site, and population characteristics that determined the health-related damages associated with emissions from coal-fired power plants. Using the Source-Receptor (SR) matrix, a reduced-form chemistry-transport model accounting based on the Climatological Regional Dispersion Model, 407 coal-fired power plants in the United States were analyzed. The paper focused on the health effects of primary formation of particulate matter 2.5 micrometers or less in diameter ($PM_{2.5}$), and the combination of SO_2 and NOx that result to the formation of secondary particulate matters. The formation of primary and secondary $PM_{2.5}$ results in premature mortality which was estimated using the value of statistical life (VSL). The paper monetized the damages across plants to be $30,000 to $500,000/t$PM_{2.5}$, $6,000 to $50,000/t$SO_2$ and $500 to $15,000/t$NO_x$. Overall, marginal damage is $0.02 to $1.57/kWh of electricity generated. This paper claimed that marginal damage is higher where population density is higher and nearer to the source of pollution.

Jaramillo and Muller (2016) estimated the externalities of $PM_{2.5}$, SO_2, NO_x, ammonia (NH_3), and Volatile organic compounds (VOC) from electric power generation, oil and gas extraction, coal mining, and oil refineries. It utilized AP2, an integrated assessment model that used six modules: emissions, air quality modeling, concentration, exposure, dose-response, and valuation. Air pollution emissions data for the years 2002, 2005, 2008, and 2011 were analyzed. For the purpose of this study, only externalities of $PM_{2.5}$, SO_2, and NOx are examined. The authors also looked at the formation of PM2.5 through the combination of SO_2 and NOx. They took it further such that not only premature mortality was considered, but also morbidity like bronchitis. Results reveal that marginal damage of GHGs in 2002 are $14,000/t$SO_2$, $2,400/t$NO_x$ and $26,000/t$PM_{2.5}$. This paper pointed out that damages from these sources have decreased significantly since 2002 while energy production increased. This implies that, considering other contributing factors, policies have successfully reduced emissions and damages.

Tol (2008) did a meta-analysis of 211 estimates from different studies and authors who contributed to the determination of carbon price. From the study, European Union used ExternE model, and assessed the cost to be $160/tC ($43.6/tCO_2). The paper considered the estimate of Stern as an outlier. Also, estimates of carbon price increases as social discount rate decreases. The authors mentioned in the study have updated their estimates in their webpages. Another economist that has a substantial research contribution to social cost of carbon (SCC) is Chris Hope.[1] He suggested that SCC may be higher than EPA's estimate and set it within the range of \$50-\$100/tCO$_2$ (Hope, 2016). These studies indicate the SCC is estimated based on climate change damages.

United States Environmental Protection Agency [US EPA] (2013) has a similar focus with Waldhoff et al. (2014) such that the paper looked at the climate change effects of the combination of CO_2, CH_4 and N_2O gases. The paper mentioned climate change damages on agricultural productivity, human health, and property damages from increased flood risk. The estimated SCC is set at \$37/tonne CO2 (\$36.26/tCO$_2$). While the social costs of CH_4 and N_2O are \$1,000/tonne (\$907.18/tCH$_4$) and \$13,000/tonne (\$11,793.40/tN$_2$O), respectively.

Tol (2011) estimated the price of carbon based on his literature survey on the SCC. A total of 13 studies were examined, and including Tol's (2011) estimate, the paper estimated that the carbon price was \$59/tC, which when converted (1tC=3.67 tCO$_2$) is equivalent to \$16/tCO$_2$. Results reveal that carbon has a net negative impact in the long run, but poorer people are more vulnerable to climate change. However, politicians are overcommitting to emission reduction targets, and that lay people may be more concerned about the impacts of climate change than experts. On the other hand, the paper admitted the uncertainty of the aggregate damage of climate change.

Nordhaus (2011) divided the world into 12 regions using the RICE-2011 model. The model used the framework of economic growth theory to estimate the damage and abatement cost of carbon. Results show SSC to be \$12/tCO$_2$. The model run different scenarios for the 12 regions. PRC, Africa and India are predicted to have among the highest cost of carbon from 2015 to 2035. The paper focused on the effects of climate change and the social costs of CO_2 due to damages to agriculture, the cost of sea-level rise, adverse impacts on health, non-market damages, as well as estimates of the potential costs of catastrophic damages.

New South Wales (NSW) EPA (2013) estimated the health damages of PM emission in different significant urban areas (SUA) with population of more than 10,000. The paper looked at different studies reporting marginal damages of particulate matters and applied it to SUA in Australia. Linear regression was used to estimate the marginal damages with respect to the area's population density. Results show that the average social cost of PM$_{2.5}$ is AUD 63,786/tonne (AUD 57,866/ton) in 2011 prices. The paper looked at PM as responsible for mortality and morbidity like hospital admissions, asthma attacks and bronchitis.

To summarize, different coal technologies have varying levels of GHG emissions, and these emissions have corresponding damages to health and the environment. Several existing studies have already estimated the cost of these damages. The values vary depending on the models of estimation that the authors used, the scope of the study, and context of the effect. The greater is the population density and the closer it is to the source of pollutant, the greater is the damage incurred. There are also disagreements as to the estimate of these costs. Some authors lean towards higher social cost of GHGs while others lean towards more conservative values.

FRAMEWORK OF THE STUDY

Efficiency is achieved when social welfare is maximized, and this occurs when the price reflects the marginal social cost. However, negative externalities like pollutants create a wedge between the marginal private cost and marginal social cost. Closing this wedge requires internalization of these externalities. This can be done by adjusting the price to reflect the damages caused by these negative externalities (Tietenberg & Lewis, 2012). This could be implemented by a corrective Pigouvian tax, which can be set at the marginal damage cost of the externality. The total social cost of an activity involves both private and external costs (Sundqvist, 2004).

The Pigouvian tax incentivizes the private producer to consider both his private costs and the unpriced externalities in his production decisions. However, the imposition of a corrective tax follows that the tax authority knows how much to charge, and that implies there is at least an estimate of the non-market value of the externality.

This paper uses a market model to illustrate the effect of externality on the price of electricity. Assume an individual consuming good (y), which is the electricity, and the vector of pollutants $X= [x1, x2,..., x_n]$ which comes along with the consumption of electricity. P_{X_i} is the price corresponding to pollutant (x_i), P_y is the price of electricity, and m is the budget for electricity. Hence, the consumer's maximization problem is,

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[1] Social cost of carbon is the marginal cost of carbon measured in \$/tCO$_2$

$$Max\ U\ (x_i(y), y)\ s.t. \textstyle\sum_{i=1}^{n} P_{x_i} x_i + P_y y \ \le m \qquad (1)$$

Each element of the vector x_i is non-decreasing as the amount of electricity y also increases. Hence $\frac{dx_i}{dy} \ge 0, \forall\ i = 1, 2, \dots, n.$

Setting up the Lagrangian:

$$\mathcal{L} = U(x_i(y), y) - \lambda(\textstyle\sum_{i=1}^{n} P_{x_i} x_i + P_y y - m) \qquad (2)$$

The first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial x_i} = U_{x_i} - \lambda(P_{x_i}) = 0$$

$$U_{x_i} - \lambda(P_{x_i}) = 0$$

$$\lambda = \frac{U_{x_i}}{P_{x_i}} \qquad \forall\ i = 1, 2, \dots, n \qquad (3)$$

$$\frac{\partial \mathcal{L}}{\partial y} = U_y - \lambda\left(\textstyle\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} + P_y\right) = 0$$

$$U_y - \lambda\left(\textstyle\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} + P_y\right) = 0$$

$$\lambda = \frac{U_y}{\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} + P_y} \qquad (4)$$

Where $\frac{dx_i}{dy}$ is the marginal damage of pollutants at price Px_i. Using equations *(3)* and *(4)* we get,

$$\frac{U_{x_i}}{P_{x_i}} = \frac{U_y}{\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} + P_y} \qquad (5)$$

Rearranging, the marginal rate of substitution in the presence of externality is:

$$MRS_{x_i, y} = \frac{U_{x_i}}{U_y} = \frac{P_{x_i}}{\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} + P_y} \qquad (6)$$

On the other hand, the firm's maximization problem in the presence of externality is:

$$Max\ \pi = P_y y - C_y y - \textstyle\sum_{i=1}^{n} P_{x_i} x_i(y) \qquad (7)$$

where $P_y y$ is the revenue of producing electricity, $C_y y$ is the cost of production and the last term, $\sum_{i=1}^{n} P_{x_i} x_i(y)$ refers to the cost of pollution during the production of y. Hence, x_i is produced only when y is produced. Getting the first order condition, we have:

$$\frac{\partial \pi}{\partial y} = P_y - C_y - \textstyle\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy} = 0 \qquad (8)$$

C_y here is the marginal cost (MC) of producing electricity while $\sum_{i=1}^{n} P_{x_i} \frac{dx_i}{dy}$ is the marginal damage cost (MDC) of pollution from electricity production. Hence from this formulation, to achieve social optimum, the price that the firm must charge should equal to his marginal cost plus the damages that the pollution creates. At equilibrium, the marginal cost is evaluated at the level $X^* = [x_1^*, x_2^*, \dots, x_n^*]$ and y* that will satisfy both equations *(6)* and *(8)*.

METHODOLOGY

Locale of the Study

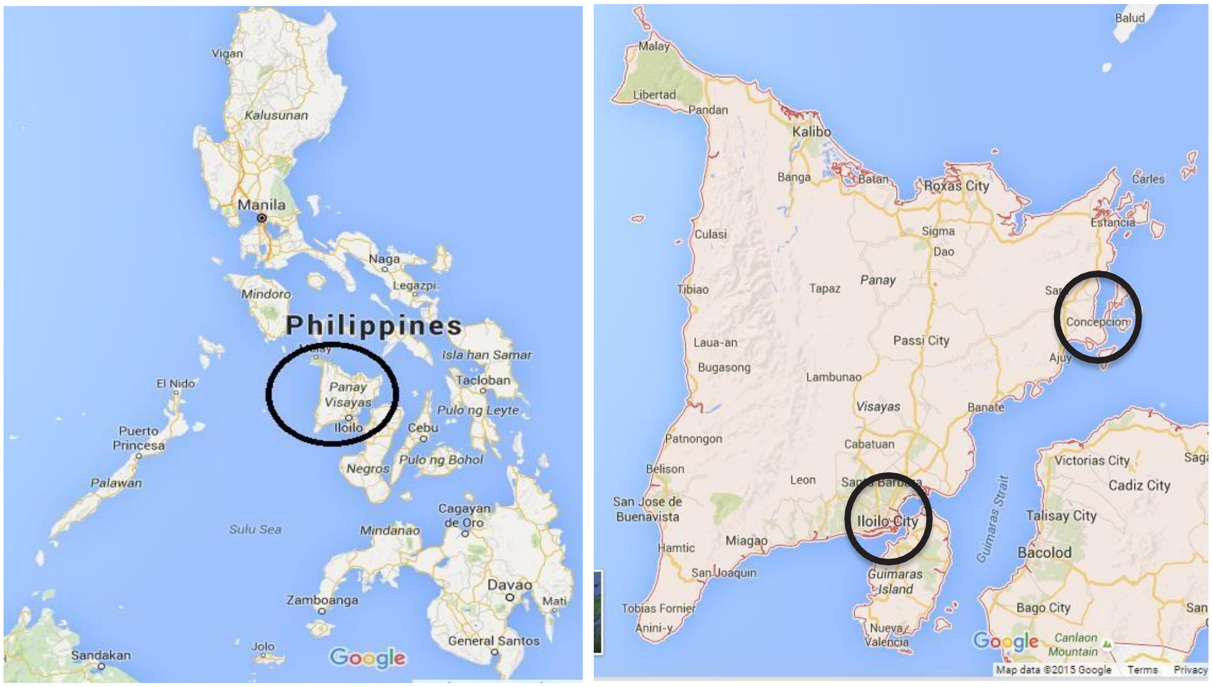
Figure 1 shows the location of Western Visayas and the towns where the coal power plants are located. It depicts the location of the region as encircled, and where Iloilo City and Concepcion can be found in Western Visayas.

The 135MW coal power in Concepcion is the first installment of the 270MW joint project of Palm Concepcion Power Corporation (PCPC). The location of the power plant is in Sitio Puntales, Brgy. Nipa, about 4 km south of Concepcion proper. The coal power utilizes advanced Circulating Fluidized Bed (CFB) technology, with a contract with PT. Pevensey Indonesia for 400,000MT/year of coal (Brown Company, Inc., 2018).

The 164 MW coal power plant owned and operated by Panay Energy Development Corporation (PEDC) was inaugurated in 2008, connected to the Visayas grid in 2010, and operated commercially in 2011. It is located Brgy. Ingore, La Paz, Iloilo City. The power plant uses the most recent circulating fluidized bed (CFB) boiler technology. This unit is said to release insignificant levels of emissions, specifically at least 95% efficiency in removing sulfur dioxide and an almost zero nitrogen oxide. It also boasts of 99.9% efficiency in capturing of total solid particles (Magkilat, 2016).

Benefit Transfer Method

From the previous section we showed that the price of the externality should equal MC plus MDC. In theory, these two are equivalent at the optimum. In case of suboptimality, the two values are not equal (Muller & Mendelsohn, 2007). These approaches require time, expertise and money. In the case where there are time and budgetary



Source: Google Map, August 23, 2016

Figure 1. Location of Iloilo City and Concepcion in Western Visayas

constraints, the WTP from these studies can be translated to WTP of a particular area of study through benefit transfer method (BTM). This study follows the suggestion of Laplante (2015) and Czajkowski and Ščasný, (2010) to use unit value BTM in order to keep the transfer error (TE) and the minimum tolerance level (MTL) minimal. Furthermore, the authors suggested an income elasticity of one. [2,3]

Laplante (2015) shows the formula for unit value transfer below:

$$V_{policy} = V_{study}\left(\frac{Y_{policy}}{Y_{study}}\right)^{\varepsilon} \qquad (9)$$

where V_{policy} is the policy site (value where the analysis is to be done), V_{study} is the study site (value of the related study), Y is the income, and ε is the income elasticity.

Externalities of different coal technologies were estimated using values from previous studies (Tol, 2008; Levy et al., 2009; Hope, 2011; Nordhaus, 2011; Tol, 2011; NSW EPA, 2013, US EPA, 2013; Waldhoff et al., 2014; Jaramillo and Muller, 2016). These studies consider individual externalities such as CO_2, NOx, SOx, CH_4, $PM_{2.5}$ and N_2O, hence the total externality cost can be calculated as the summation of these individual impacts. Using the value transfer method, the values of individual externalities are adjusted using the ratio of the GDP per capita of Philippines and that of country where the study was conducted, or where the currency was based. This adjustment is done to adjust the WTP of the country of reference with the WTP of Philippines.

The value is adjusted further using the PPP adjusted exchange rate.[4] The PPP adjustment is due to the difference in the value and purchasing power of currency of different countries. The value is then adjusted using GDP deflator. This is to adjust to the inflation throughout the years. Income elasticity of demand is set to 1.0. We operationalize equation *(9)* by applying these adjustments to arrive at the cost of a specific GHG externality as:

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[2] Transfer error is also called generalization error. This is the difference between a transferred estimate and a primary study estimate specific to the transfer context or site, where the latter is presumed to reflect an unbiased estimate of the true value (Rosenberger & Johnston, 2013).

[3] The minimum tolerance level is the minimum difference that would result in the rejection of the null hypothesis of equivalence of two values. This measure not only looks at the difference in the values, it also considers the uncertainty with which they are known (Kristofersson & Navrud, 2005; Czajkowski & Ščasný, 2010, in Czajkowski et al., 2017).

[4] Adjustments are made using the PPP conversion factor, where Purchasing Power Parity conversion factor is the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as U.S. dollar would buy in the United States. (World Bank, 2016).

$$\bar{V}_{SC_k(2015),Ph} = V_{SC_k,t,ref}\left(\frac{Y_{t,Ph}}{Y_{t,ref}} * PPP_{t,Ph,ref} * \delta_{t,Ph,2015}\right)^1 \qquad (10)$$

where k is a particular GHG (i.e. CO_2), $\bar{V}_{SC_k(2015)}$ is the value of the social cost of GHG k, set at year 2015, ref is the country of reference, where the related study was conducted or currency was based, t is the time the analysis was conducted, $\frac{Y_{t,Ph}}{Y_{t,ref}}$ is the GDP per capita ratio between Philippines and country of reference, $PPP_{t,Ph,ref}$ is the purchasing power parity of Philippines with respect to the country of reference at the time of analysis, and $\delta_{t,Ph,2015}$ is the Philippine GDP deflator from the time of analysis.[5]

It can be noted that the unit of this value is set at currency per ton of GHG (e.g. $/t$CO_2$).[6] Hence, the externality of this GHG can be determined by plugging in to the formula below:

$$E_{i(2015)} = \sum_k \left(\frac{Em_{i,k} * V_{SC_k(2015)}}{NG_i}\right) \qquad (11)$$

where $Em_{i,k}$ is the emission in tons of a particular GHG and NG_i refers to the annual net generation of the power plant. Note that $\frac{Em_{i,k}}{NG_i}$ is the emission intensity of plant i for pollutant k. The emission intensity reflects the amount in tons that the coal plant releases per MWh. Hence, $E_{(2015)}$ is the weighted average of the damages incurred by different pollutants, where the weights are the emission intensities. Utilizing the data gathered of the two power plants (see Tables 4 and 5), the values of externalities were computed using the formulas above. Emissions of CO_2, SOx and NOx of coal technologies were taken from related studies (see Table 1), while emissions of other gases (i.e. CH_4, N_2O and PM) were taken from North American Power Plant (2016) website.[7]

Data Sources

Data gathered for this study were from the Philippine Statistics Authority (PSA), Energy Regulatory Commission (ERC), North American Power Plant (2016), Economy Watch and the World Bank. Some data used are from other studies as listed in Chapter 3. Table 4 below shows the emission rate of each major type of

Table 4. GHG Emissions of Clean Coal Technology

Type of Technology	GHG Pollutant	Emission Level (t/MWh)
From Related Studies		
PF	CO_2	0.82 – 0.99 without capture technology; 0.093 - 0.129 with capture technology
	SO_x	<0.00001 - 0.00026
	NO_x	0.00011 - 0.00083
IGCC	CO_2	0.82 - 0.93 without capture technology; 0.157 - 0.168 with capture technology
	SO_x	0.00001
	NO_x	0.00007 - 0.0006
CFB	CO_2	0.88 - 1.01
	SO_x	0.00026
	NO_x	0.00043
From North American Power Plant Data Set (based from actual emissions of 40 power plants using CFB technology)		
CFB	CO_2	1.10664
	$PM_{2.5}$	0.00031
	SO_x	0.00651
	NO_x	0.00203
	CH_4	0.00001
	N_2O	0.00002

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[5] See https://www.indexmundi.com/facts/philippines/gdp-deflator.

[6] 1 ton = 0.907185 tonne (or metric ton); 1 ton = 907.185 kg.

[7] See http://www2.cec.org/site/PPE/

clean coal technology based on the data gathered.

Information about the coal power owned and operated by Panay Energy Development Corporation (PEDC) were taken from ERC. ERC Cases No. 2011-105 RC and No. 2010-097 RC summarize the features of the power plant in Table 5. The power plant is using a CFB boiler technology and based on the GHG emission rates of CFB boiler technology from Table 5, the emissions in tons per year of PEDC are estimated.

As for the coal power owned by Palm Concepcion Power Corp. (PCPC), there are no details about its power generation per year. The new power plant adopts the same technology used by PEDC coal power, hence assuming that it has the same capacity and load factor, its features are presented in Table 6.

Table 7 summarizes the externalities gathered from different studies (see Tables 1 and 2). However, if estimates in the study were done before the year 2000, these are excluded in the analysis because of the changes in technology and emissions over the

Table 5. Salient Features of PEDC Coal Power Plant in Iloilo City

Type of Plant	**Circulating Fluidized Bed (CFB) coal fired power plant**
Installed Capacity	Two (2) units of 82 MW or 164 MW
Gross Generation Per Year	1,030,176,000 kWh at 80% capacity factor and 100% load factor
Net Generation Per Year	772,632,000 kWh
CO_2 Emission Per Year	906,555 – 1,140,034 tons**
CH_4 Emission Per Year	10 tons**
NO_x Emission Per Year	443 – 2,091 tons**
N_2O Emission Per Year	21 tons**
SO_x Emission Per Year	268 – 6,706 tons**
$PM_{2.5}$ Emission Per Year	319 tons**
Type of Operation	Base load plant
Economic Life	25 years

Source: ERC, 2011
**Values estimated using data from table 4 multiplied to gross generation

Table 6. Salient Features of PCPC Coal Power in Concepcion, Iloilo

Type of Plant	**Circulating Fluidized Bed (CFB) coal fired power plant**
Installed Capacity	One (1) unit of 135 MW
Gross Generation Per Year	848,011,000 kWh at 80% capacity factor and 100% load factor
Net Generation Per Year	636,008,000 kWh
CO_2 Emission Per Year	746,250 – 938,443 tons**
CH_4 Emission Per Year	8 tons **
NO_x Emission Per Year	365 – 1,721 tons**
N_2O Emission Per Year	17 tons **
SO_x Emission Per Year	220 – 5,521 tons**
$PM_{2.5}$ Emission Per Year	263 tons **
Type of Operation	Base load plant
Economic Life	25 years

**Values imputed using data from table 4 multiplied to gross generation

Table 7. Summary of Pollution Cost of Greenhouse Gases from Selected Studies

Study	Place of Study/ Currency Used	Base Year	($/t$CO_2$)	($/t$CH_4$)	($/t$PM_{2.5}$)	($/t$SO_x$)	($/t$NO_x$)	($/t$N_2O$)
European Union (in Tol, 2008)	World/USD	2008	43.6					
Levy et al. (2009)	USD	2009			30,000	6,000	500	
US EPA (2013)	USD	2010	36.26	984				12,792
Tol (2011)	World/USD	2011	16					
Nordhaus (2011)	World/USD	2011	11.81					
NSW EPA (2013)	Australia/ AUD	2011			57,866[a,b]			
Waldhoff et al. (2014)	World/USD	2007	9.1	313				4,360
Hope (2011)	World/USD	2011	75[a]					
Jaramillo and Muller (2016)	USD	2002			26,000	14,000	2,400	

[a] midpoint of the estimated range was taken

[b] in AUD

years. Jaramillo and Muller (2016) claimed that social costs from emissions have significantly decreased since 2000, supporting the decision in this study. Table 7 shows the social costs of greenhouse gases, study where the values were taken, the currency used or the study was conducted, and the base year. When base year was not mentioned in the study, this paper makes use of the publication year as the proxy base year. This can result to biases in the estimates.

RESULTS AND DISCUSSION

Utilizing the data from the previous section, the externalities were computed using the equations *(10)* and *(11)*. Table 8 below summarizes the computation of externalities of GHG emissions from different studies for PEDC and PCPC coal power.

Unfortunately, the analysis does not take into consideration the population density of the two areas. PEDC is in an urban area while PCPC is in a rural area. Theoretically, the marginal social cost of PEDC emissions should be higher because more people are affected. There is a gap in the information on the emission of the power plants and the people that are actually affected by these emissions. However, the estimate provides a range of externalities, which means that PCPC power, located in a remote and less populated area, most likely cause damage on the lower end of the range. The table further shows that marginal damage of CO_2 emissions can be between PhP 0.02786 - 0.35007/kWh, CH_4 to be PhP 0.00001/kWh, SOx to be PhP 0.00160 - 0.07375/kWh, NOx to be PhP 0.00022 - 0.00394/kWh, $PM_{2.5}$ to be PhP 0.00651 - 0.01148/kWh and N_2O to be PhP 0.0003/kWh. Table 9 sums up the total externalities below:

The computed total externalities of a CFB coal power implies that a Pigouvian tax of this amount can be implemented to correct for the market inefficiency. The effective rate for residential customer charged by Panay Electric Company (PECO) in Iloilo City is Php 10.7627/kWh.[8] Furthermore, the effective residential rate of Iloilo Electric Cooperative 1 (ILECO 1) in rural areas is Php 11.3442/kWh, ILECO 2's effective rate is 10.9465/kWh while that of ILECO 3, where Concepcion belongs, is Php 11.5439/kWh.[9,10,11] Assuming that the consumers shoulder the cost of externalities, this implies that the price of electricity in Iloilo City would increase by 0.7% to 4.1%, areas covered by ILECO 1 would increase by 0.67% to 3.88%, ILECO 2 coverage would increase by 0.69% to 4%, and ILECO 3 would increase its prices by 0.65% to 3.8%.

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[8]. See http://www.kuryente.org.ph/electric-company/rates/132

[9] See http://www.kuryente.org.ph/electric-company/rates/60

[10] See http://www.kuryente.org.ph/electric-company/rates/61

[11] See http://www.kuryente.org.ph/electric-company/rates/62

Table 8. Values of GHG Externalities for PEDC and PCPC Coal Power Plants

Study	Value of CO$_2$ (in \$/t)	V_{SC} (in PhP/t)	E^{CO2} (in PhP/kWh)
European Union (in Tol, 2008)	43.6	119.17	0.13982 - 0.17583
US EPA (2013)	36.26	31.27	0.03668 - 0.04613
Tol (2011)	16	50.61	0.05939 - 0.07468
Nordhaus (2011)	11.81	37.36	0.04383 - 0.05512
Waldhoff et al. (2014)	9.1	23.75	0.02786 - 0.03504
Hope (2011)	75	237.25	0.27837 - 0.35007
	Value of CH$_4$	V_{SC}	E^{CH4}
US EPA (2013)	984	848.46	0.00001
Waldhoff et al. (2014)	313	816.74	0.00001
	Value of SOx	V_{SC}	E^{SOx}
Jaramillo and Muller (2016)	14,000	8,496.03	0.00295 - 0.07374
Levy et al. (2009)	6,000	4,614.69	0.00160 - 0.04005
	Value of NOx	V_{SC}	E^{NOx}
Jaramillo and Muller (2016)	2,400	1,456.46	0.00083 - 0.00394
Levy et al. (2009)	500	384.56	0.00022 - 0.00104
	Value of PM$_{2.5}$	V_{SC}	$E^{PM2.5}$
Jaramillo and Muller (2016)	26,000	15,778	0.00651
Levy et al. (2009)	30,000	23,073	0.00953
NWS EPA	57,866[a]	27,811	0.01148
	Value of N$_2$O	V_{SC}	E^{N2O}
US EPA (2013)	12,792	11,029.98	0.00030
Waldhoff et al. (2014)	4,360	11,377	0.00031

[a] in AUD
PPP source: World Bank (2016)
GDP per Capita source: World Bank (2016)
GDP Deflator source: Economy Watch (2016)

Table 9. Total Externalities of a CFB Coal Power (in PhP/kWh)

Min	Max	Mean
0.07577	0.44058	0.159816667

On the other hand, if the two power plants were to shoulder the cost of externalities, PEDC power plant would pay the annual tax amounting PhP 78,056,435 to PhP 453,874,942, while PCPC power plant can be taxed annually from PhP 64,253,793 to PhP 373,616,686.[12,13] However, since PCPC is located in a rural area with lower population, the tax can be based on the lower range. In 2017, Bureau of Internal Revenue targeted a tax collection of PhP 13 Billion from Panay and Guimaras Islands (Iloilo Metropolitan Times, 2017a). The total additional tax that can be collected from these two power plants would be PhP 142,310,228 to PhP 518,128,735. This translates to an increase in tax collection of 1.08% to 3.93%. The tax collected can be allotted as compensation for the damages caused by these GHG emissions.

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[12]. Values were computed by multiplying gross generation of PEDC to the range of externalities (1,030,176,000 kWh times PhP 0.07577 or 0.44058/kWh)

[13] Values were computed by multiplying gross generation of PCPC to the range of externalities (848,011,000 kWh times PhP 0.07577 or 0.44058/kWh)

CONCLUSION AND RECOMMENDATIONS

The continuous development in Western Visayas require a stable source of electricity at a low price. The abundance and stability of coal makes it a dominant choice among key players in the energy sector in the region. However, environmental and social concerns demand that producers pay for the social damages that they cause. The three modern coal technologies that produce cleaner coal are PF, CFB and IGCC. PF is a mature technology, but IGCC emits the lowest emissions among the three. PEDC and PCPC coal power from Western Visayas both employ CFB coal technology, which is known because of its low capital cost. The emission levels of CFB and PF are comparable.

The Benefit Transfer method used in this study utilizes other studies and transfers their respective results in the site in focus by adjusting for WTP, purchasing power between countries, and inflation. GDP per capita, PPP and GDP deflator were used as means to adjust the values. With this, pollution costs of GHGs such as CO_2, NOx, SOx, CH_4, $PM_{2.5}$ and N_2O were estimated and summed up to value the total externalities of these two power plants. Based on the results of the study, the two power plants have total externalities ranging from PhP 0.08 to PhP 0.44 per kilowatt-hour, with PCPC power taking the lower range of this externality. The amount of tax should be equal the cost of externality, and this can cause the current effective electricity rate to increase by 0.65 to 4.1 percent. Multiplying these amounts to their respective gross generation, PEDC can be taxed an amount of PhP 78,056,435 to PhP 453,874,942 per year while PCPC can be taxed at least PhP 64,253,793 per year. The tax collected as “payment” for cost of externalities can be used to fund the damages linked with GHG emissions.

Due to the nature of BTM, this study has inherent limitations. Ideally, values can easily be transferred if the conditions and characteristics of the related study site and the place where the analysis is to be conducted (in this case, Western Visayas) are similar. Unfortunately, many of these studies do not indicate specifications that can be the basis for comparison (i.e. environmental characteristics). There may be cost of damages not applicable to Western Visayas, and there may be cost of damages in the region that are not accounted for by related studies. However, a range of values is provided by this paper and the cost of externalities may fall within this range.

The limitations of this paper suggest that local effects of GHGs, particularly PM, can be a topic for future researches. For one, population density varies between places. Also, there may be other environmental effects since there are community based MPAs in the vicinity of the two coal power plants. On the other hand, this method can be applied to other coal power plants using the same or other clean coal technology in the country. This can help determine the value of externalities even with limited resources. Another area for research is comparing coal technology with other energy source (i.e. natural gas or renewables). With the integration of externalities, this can help determine which source of energy has less cost and thus, a better technology to use.

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