

ENVIRONMENTAL IMPACT OF ENERGY GENERATION AND CONSUMPTION IN THE SOCIETY

ABSTRACT

The impact of energy in our society is a subject that needs attention. We use motorcycle, cars, and other materials/machines/processes emitting dangerous gases into the atmosphere everyday without been cautious of the associated risk such as acid rain precipitation, ozone layer depletion and global warming. Scientist, engineers and broadcaster have tried in many ways to help create awareness and reduce the usage/deployment of these materials/processes.

One major progress, scientists and engineers have, made in the past few decades is the improvement in energy efficiency, via direct energy conversion systems, which have consequently led to direct environmental benefit.

INTRODUCTION

Energy resources are all forms of energy used in the modern world, either for heating, generation of electricity or for conversion of processes from one form to another. Energy resources can be roughly classified into three categories: fossils, renewable and nuclear energy.

Fossil energy are obtained from the dead plants and animals deposit created over the long history of the planet. These resources are vast but limited, and are not renewable. Until recently, fossil fuel have provided for the majority of the humanity energy demands. These resources mainly include crude oil and natural gas.

Renewable source of energy are source of energy that are naturally replenished on earth/ example of traditionally renewable energy source include, but not limited to, the hydropower and biomass (e.g. plant fuel such as wood, traditionally have been used throughout the world mainly for heating). Biomass energy resources are known for their carbon neutral properties.

Deposit of certain radioactive element on earth crust can be classified as nuclear energy resources. These resources are used for nuclear fission based power plants for energy generation. The amount of these rare radioactive element are limited on our planet and cannot be replenished - non-renewable.

These energy resources are usually explored, exploited and converted from their raw forms to usable forms, either via direct or indirect energy conversion processes, during energy generation. For complex processes of indirect conversion of fossil and nuclear energy resources, there are usually emissions of dangerous substances which negatively impact the environment. Some of these negative environmental impact resulting from energy generation from these resources include, but not limited to, acidic rain precipitation, stratospheric ozone layer depletion and global warming. Energy consumption, which is usually associated with affluent life style, also yield dangerous emission of substances such as carbon dioxide to the atmosphere from automobiles and coal, CFCs from refrigerants etcetera. In the past, several solutions to remediate these negative environmental impact have been suggested and these include, but not limited to,

National Engineering Science and Technology Essay Competition (NESTEC)

energy conservation through improved energy efficiency and switching from fossil fuel and nuclear energy resources to more environmental friendly energy forms i.e. increased use of renewable energy resources.

The aim of these research is to highlight the environmental impact of energy generation and consumption with specific objectives of highlighting the effects of the negative environmental impact, from energy generation and consumption, and the environmental benefits of improving energy efficiency, via some case studies, in attaining sustainable development.

Negative Environmental Impact Of Energy Generation And Consumption In The Society

Pre industrial revolution saw that the use of wood as a source of energy to power different activities, these produce a lot of CO₂ which is then absorbed by plant and animals and converted back to carbon for use as fuel again. The inability of the wood to meet up with the societal demand along with other environmental issues gave rise to the industrial revolution which began with the use of fossil fuels e.g. oil, coal and gas. These increase the concentration of CO₂ in the air and gave birth to global warming. Global warming is gaining more awareness and researchers and policy makers have focused on related issue by considering energy, environment and sustainable development.

World population is expected to double by the middle of 21st century and economic development will certainly continue to grow. Global demand for energy is also expected to grow as much as order of magnitude by 2050, while primary energy demand are also expected to increase by 1.5-3 times. Simultaneous concerns will likely increase regarding energy related environmental problems such as acid precipitation, stratospheric ozone depletion and global climatic changes (greenhouse effect). Consequently, energy is one of the main factor to be considered when discussing sustainable development. That's why energy production and consumption plays a vital role in the society.

Sustainable development is a development that meet the needs of the present without compromising the ability of the future to meet their own needs. One of the most important factor that contributes to attaining sustainable development is energy resources that's fully sustainable.

In order to develop an understanding of the issues associated with the global carbon emission, it is necessary to comprehend the relationship between urban growth and energy use. The energy needs of the cities are large and increase with both urban growth and industrial development. Urbanization entails not only change in land use pattern but also shift in the way in which societies use energy. It accelerates the natural transition away from natural fuel (e.g. fire wood, charcoal and crop residues) towards modern fuels (e.g. petroleum, fuel electricity).

Climate change possesses an altogether different kind of energy challenges. Air pollutant resulting from energy consumption that leads to acid rain can be remediated in part by administrative measures, such as vehicle exhaust standards or emission limits for power stations. Technical measures such as fitting flue gas cleaning equipment or catalytic converters could also be deployed. However, emissions of greenhouse gases are so dispersed that it is not possible to take this local relatively limited approach in dealing with climatic changes. The nature of these problems demands a more comprehensive energy policy response which influences the action of energy production and consumption in all countries.

The global problem that could arise from the production and consumption of energy includes:

- i. Acid precipitation
- ii. Stratospheric ozone depletion
- iii. The greenhouse effect (climatic changes)

Acid Precipitation

Acids produced by consumption of fossil fuels, in industrial boilers, gas turbines and transportation vehicles, can be transported over a great distance through the atmosphere and deposited via precipitation on earth and on ecosystems that are exceedingly vulnerable to damage from excessive acidity. Emissions of SO_2 and NO contribute to acid precipitation with local concerns related to health. Acid precipitation is a broad term that includes any form of precipitation with acidic components, such as sulphuric or nitric acid that falls to the ground from the atmosphere in wet or dry form. These can include rain, snow, fog, hail or even dust that's acidic.

Some energy-related activities are major sources of acid precipitation. For example, electric power generation, residential heating and industrial energy use, which account for huge SO_2

when exposed to air. Road transports are important source of NO. Some natural sources include rotting vegetation and erupting volcanoes which release some chemicals that can cause acid rain, but most sources of acid rain are anthropogenic. The biggest sources are coal-burning power plants, factories, and automobiles.

When humans burn fossil fuels, sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are released into the atmosphere. Those air pollutants react with water, oxygen, and other substances to form airborne sulfuric and nitric acid. Winds may spread these acidic compounds through the atmosphere and over hundreds of miles. When acid rain reaches the Earth, it flows across the surface in runoff water, enters water systems, and sinks into the soil. These brings infertility to the soil and making plantation difficult to survive.

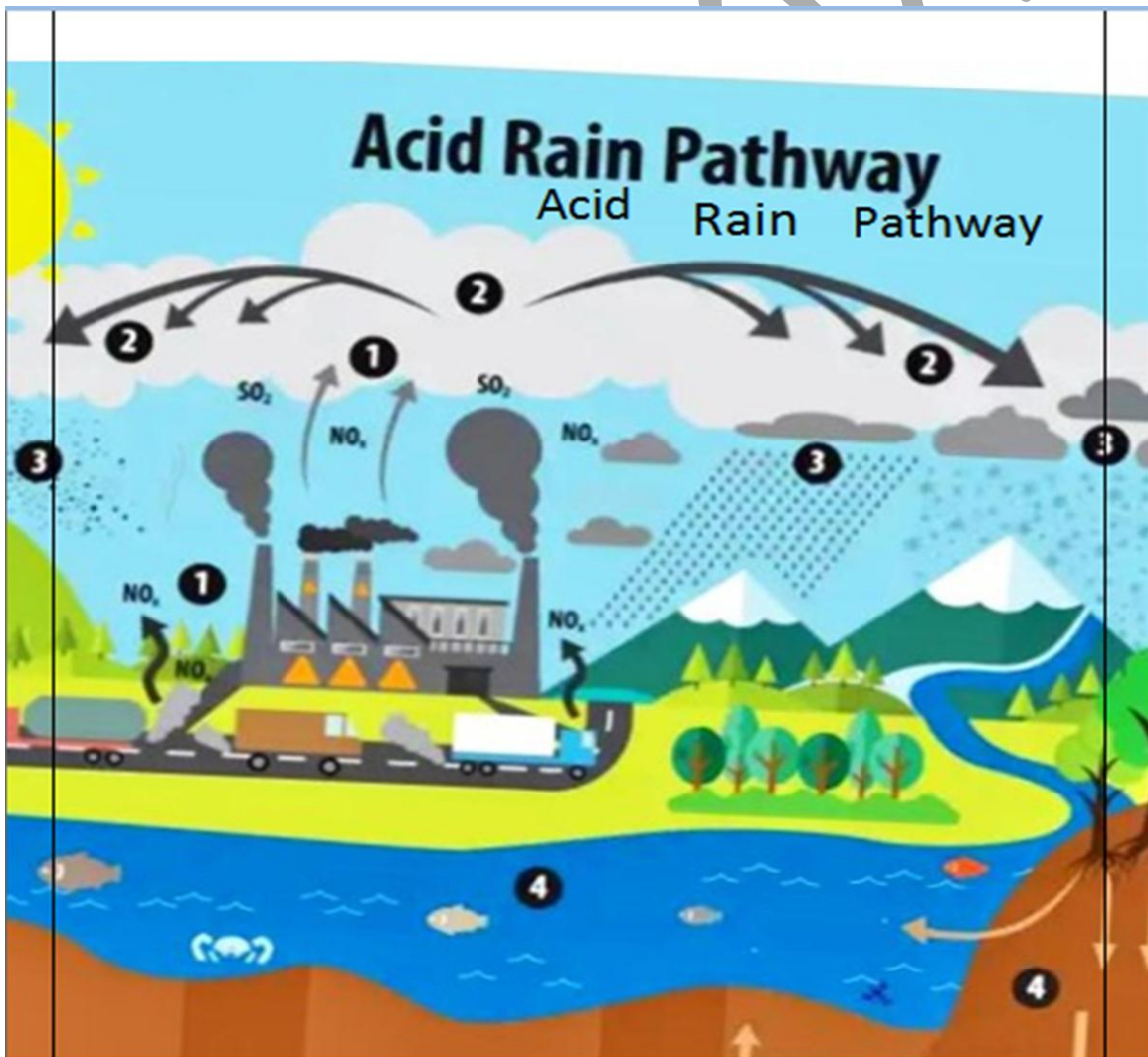


Figure 1: Acid rain pathway

Environmental Effect of Acid Precipitation

Sulfur dioxide and nitrogen oxides are not primary greenhouse gases that contribute to global warming, one of the main effects of climate change; in fact, sulfur dioxide has a cooling effect on the atmosphere. But nitrogen oxides contribute to the formation of ground-level ozone, a major pollutant that can be harmful to people. Both gases cause environmental and health concerns because they can spread easily via air pollution and acid rain.

Acid rain has many ecological effects, especially on lakes, streams, wetlands, and other aquatic environments. Acid rain makes such waters more acidic, which results in more aluminum absorption from soil that is carried into lakes and streams. That combination makes waters toxic to crayfish, clams, fish, and other aquatic animals.

Some species can tolerate acidic waters better than others. However, in an interconnected ecosystem, what affects some species eventually affects many more throughout the food chain, including non-aquatic species such as birds.

Acid rain and fog also damage forests, especially those at higher elevations. The acid deposits rob the soil of essential nutrients such as calcium and cause aluminum to be released in the soil, which makes it hard for trees to take up water. Trees' leaves and needles are also harmed by acids.

The effects of acid rain, combined with other environmental stressors, leave trees and plants less healthy, more vulnerable to cold temperatures, insects, and disease. The pollutants may also inhibit trees' ability to reproduce. Some soils are better able to neutralize acids than others. But in areas where the soil's "buffering capacity" is low, such as parts of the U.S. Northeast, the harmful effects of acid rain are much greater.

Acid deposits damage physical structures such as limestone buildings, artifacts and cars. When acid rain takes the form of inhalable fog, acid precipitation can cause health problems including eye irritation and asthma.

Stratospheric Ozone Depletion

It is well known that the ozone present in the stratosphere, roughly at an altitude of 12 and 25km, plays a natural equilibrium maintaining role for the earth, through absorption of ultraviolet (UV) radiation. A global environmental problem is the distortion and regional depletion of the stratospheric ozone layer, which has been showed to be caused by emission of

chlorofluorocarbons (CFCs), halons (chlorinated and brominated organic compounds) and N₂O. Ozone depletion in the stratosphere can lead to increase level of damaging ultra violet radiation reaching the ground, causing environmental problems in the ecosystem and to many biological species.

Energy related activities are only partially responsible for the emissions which lead to the stratospheric ozone depletion. Though, energy activities such as fossil fuel and biomass combustion account for 65% to 75% of anthropogenic N₂O emission; chlorofluorocarbons (CFCs) which are used in air conditioning and refrigerating equipment as refrigerant and in foam insulation as blowing agent, plays the most important role in ozone depletion.

The ozone layer in the stratosphere absorbs a portion of the radiation from the sun, preventing it from reaching the planet's surface. Most importantly, it absorbs the portion of UV light called UVB. UVB has been linked to many harmful effects, including skin cancers, cataracts, and harm to some crops and marine life. Naturally there exist in the stratosphere ozone formation reaction and ozone destruction reactions which is a occurs in a cycle called the chlorine catalytic cycle. These two reactions occur simultaneously in the layer thereby maintaining a steady concentration of ozone in this layer. However, when the destruction rate supersedes the formation rate, then the concentration of ozone in the layer gradually reduces thereby increasing the chances of UV rays escaping to the earth surface.

Scientists have established records spanning several decades that detail normal ozone levels during natural cycles. Ozone concentrations in the atmosphere vary naturally with sunspots, seasons, and latitude. These processes are well understood and predictable. Each natural reduction in ozone levels has been followed by a recovery. Beginning in the 1970s, however, scientific evidence showed that the ozone shield was being depleted well beyond natural processes.

Environmental Effect of Stratospheric Ozone Depletion

The environmental effect of ozone depletion can be seen differently on different species depending on their habitat and the ecosystem to which they belongs.

Ozone layer depletion increases the amount of UVB that reaches the Earth's surface. Laboratory and epidemiological studies demonstrate that UVB causes non-melanoma skin cancer and plays a major role in malignant melanoma development. In addition, UVB has been linked to the

development of cataracts, a clouding of the eye's lens. Because all sunlight contains some UVB, even with normal stratospheric ozone levels, it is always important to protect your skin and eyes from the sun.

UVB radiation affects the physiological and developmental processes of plants. Despite mechanisms to reduce or repair these effects and an ability to adapt to increased levels of UVB, plant growth can be directly affected by UVB radiation. Indirect changes caused by UVB (such as changes in plant form, how nutrients are distributed within the plant, timing of developmental phases and secondary metabolism) may be equally or sometimes more important than damaging effects of UVB. These changes can have important implications for plant competitive balance, herbivory, plant diseases, and biogeochemical cycles.

Phytoplankton form the foundation of aquatic food webs in marine environment. Phytoplankton productivity is limited to the euphotic zone, the upper layer of the water column in which there is sufficient sunlight to support net productivity. Exposure to solar UVB radiation has been shown to affect both orientation and motility in phytoplankton, resulting in reduced survival rates for these organisms. Scientists have demonstrated a direct reduction in phytoplankton production due to ozone depletion-related increases in UVB. UVB radiation has been found to cause damage to early developmental stages of fish, shrimp, crab, amphibians, and other marine animals. The most severe effects are decreased reproductive capacity and impaired larval development. Small increases in UVB exposure could result in population reductions for small marine organisms with implications for the whole marine food chain.

Increases in UVB radiation could affect terrestrial and aquatic biogeochemical cycles, thus altering both sources and sinks of greenhouse and chemically important trace gases (e.g., carbon dioxide, carbon monoxide, carbonyl sulfide, ozone, and possibly other gases). These potential changes would contribute to biosphere-atmosphere feedbacks that mitigate or amplify the atmospheric concentrations of these gases.

Synthetic polymers, naturally occurring biopolymers, as well as some other materials of commercial interest are adversely affected by UVB radiation. Today's materials are somewhat protected from UVB by special additives. Yet, increases in UVB levels will accelerate their breakdown, limiting the length of time for which they are useful outdoors.

The Greenhouse Effect (Global Climate Change)

The most important environmental problem relating to energy utilization is global climate change, also known as the global warming resulting from the negative effect of greenhouse effect. The major source of energy to the earth is the sun. The sun energy is absorbed by the earth surface as visible light and emitted back to the atmosphere as infra red heat (with a higher wave length than the incident visible light). This energy is captured by the atmospheric gases (majorly by the green house gases) which eventually keeps the atmosphere warm and makes it able to support complex life. However, if the atmosphere contains excess of these greenhouse gases, excessive heat retention, which raises the atmospheric temperature, can occur thereby leading to the term global warming. The most abundant greenhouse gas, in the atmosphere, is water vapor. The next in abundance is CO₂, followed by methane and NO_x. Currently it is estimated that CO₂ contributes about 50% to the anthropogenic greenhouse effect. Energy-related human activities that contribute to the increase in the atmospheric concentration of various greenhouse gases are, CO₂ released from the fossil fuel combustion, methane emission, which partly arise from natural gas leaks and coal mining, all contribute to the greenhouse effect. The earth surface temperature has increased about 0.6°C over the last century, and as a consequence sea level is estimated to have risen by perhaps 20 cm. Furthermore, many scientist have predicted that if atmospheric concentration of greenhouse gases continue to increase as present trends in fossil fuel consumption suggest will occur, the earth temperature may increase in the next century by another 2°C and perhaps by up to 4°C. If this prediction is realized, sea level could rise between 30 cm and 60 cm before the end of the 21st century.

One major remedy to this global warming is an all-encompassing policy options for stabilizing climate change. With a rapidly changing world, it is possible to restrain emission of green house gases considerably through effort aimed specifically at changing patterns of energy production and use (e.g the implementation of energy conservation measures, increased use of biomass fuels and some fuel switching, replacement of internal combustion fuel cars with electric cars, partial or full replacement of thermal power plants with renewable power sources etc). Adoption of such measures may reduce the rate of global warming. This climatic stabilizing strategies will be more effective when complied to by both developing and developed nations. CO₂ emission can be reduced through energy efficiency improvement and fuel-switching measures.

A balance between economic development and emission abatement (especially in developing countries) requires the adoption of domestic policies aimed at improving the efficiency of energy used and facilitating fuel switching, and the implementation of international policies enabling easy access to advance technologies and external resources. Hence, the greatest opportunity for reducing emission in developing countries lies in improving energy efficiency as the prospect of importing cleaner fuels appear bleak.

Achieving improved energy efficiency requires a concerted effort on the part of consumer, manufacturer, energy supplying companies and government. This may require large industries to prepare an energy efficiency in pass statement and providing incentives for reduced energy use in the form of tax breaks. Incentives for the accelerated replacement and the commissioning of existing low efficiency equipments, can also help reduce the energy currently wasted in carrying out many end-use activities.

While improving energy efficiency can slow somewhat the growth of energy use and carbon emissions, it will not reverse the trend in many developing country towards using increasing amount of energy to support economy growth. To decrease drastically the energy requirements of economy development would require fundamental changes in the way societies develop.

The major causes of the greenhouse effect are: burning of fossil fuel, deforestation, use of fertilizers in farming, improper designed landfills etc.

Environmental Effect of Greenhouse Effect

One major environmental effect of green house effect global warming. It is the phenomenon of a gradual increase in the average temperature of the Earth's atmosphere. The main cause for this environmental issue is the increased volumes of greenhouse gases such as carbon dioxide and methane released by the burning of fossil fuels, emissions from the vehicles, industries and other human activities.

Ozone layer depletion can also be said to result from the accumulation of CFC which is also a greenhouse gas, hence all environmental issues associated with ozone layer depletion could also be regarded as effect of greenhouse gases accumulation

Smog, which is a secondary air pollutant, is formed by the combination of smoke and fog. It can result from both by natural means and anthropogenic means. In general, smog is generally formed by the accumulation of more greenhouse gases including nitrogen and sulfur oxides. The

major contributors to the formation of smog are the automobile and industrial emissions, agricultural fires, natural forest fires and the reaction of these chemicals among themselves

Positive Environmental Impact Of Energy Conservation In The Society

A number of factors are considered to be important in determining the future level of a country's energy consumption and production, including population growth, economic performance, consumer preferences, technological developments, government policies concerning the energy and other sectors, and developments on world energy markets.

Energy conservation involves efficiency improvements, formulation of appropriate pricing policies, and good 'housekeeping practices' and load management strategies, among other measures. A significant reduction in consumer energy cost can occur if conservation measures are adopted appropriately.

For societies to attain or try to attain sustainable development, much effort must be devoted not only to discovering sustainable energy resources, but also to increasing the energy efficiencies of processes utilizing these resources. Increasing the efficiency of energy-utilizing devices is therefore important.

Most energy efficiency improvement leads to direct environmental benefits and examples of the environmental benefits attainable from energy efficiency improvement are considered as case studies in this research as follows:

Case study I:

Operating energy input requirements are reduced per unit output and pollutants generated are correspondingly reduced. For example considering two systems of Gas Turbine Plants (GTP) as follows:

System I: Convectional GTP

System II: GTP incorporated with Chemical Looping Combustion (CLC)

GTP incorporated with CLC uses metal oxide as oxygen carrier as against compressed air in convectional GTP. For system II, the input energy requirement is reduced because the shaft work done in compressing air, in the case of convectional GTP, is absent for the GTP incorporated with CLC.

Hence,

$$Eff_I = \left[\frac{\text{Output Energy}}{\text{input Energy}} \right]_I \quad 1$$

$$Eff_{II} = \left[\frac{\text{Output Energy}}{\text{input Energy}} \right]_{II} \quad 2$$

Considering a unit energy output as a basis for both GTP systems:

$$(\text{Output Energy})_I = (\text{Output Energy})_{II} \quad 3$$

Considering the absence of shaft work in system II,

$$(\text{Input Energy})_I > (\text{Input Energy})_{II} \quad 4$$

Therefore,

$$Eff_I < Eff_{II} \quad 5$$

However from energy balance,

$$\text{Input Energy} = \text{Output Energy} + \text{Energy losses through flue gasses} \quad 6$$

Hence

$$(\text{Input Energy})_I = (\text{Output Energy})_I + (\text{Energy losses to flue gasses})_I \quad 7$$

$$(\text{Input Energy})_{II} = (\text{Output Energy})_{II} + (\text{Energy losses to flue gasses})_{II} \quad 8$$

Rearranging equation 7 and 8, gives

$$(\text{Output Energy})_I = (\text{Input Energy})_I - (\text{Energy losses to flue gasses})_I \quad 9$$

$$(\text{Output Energy})_{II} = (\text{Input Energy})_{II} - (\text{Energy losses to flue gasses})_{II} \quad 10$$

Substituting equation 9 and 10 into equation 3, we have

$$(\text{Input Energy})_I - (\text{Energy loses to flue gasses})_I = (\text{Input Energy})_{II} - (\text{Energy loses to flue gasses})_{II} \quad 11$$

$$(\text{Input Energy})_I - (\text{Input Energy})_{II} = (\text{Energy loses to flue gasses})_I - (\text{Energy loses to flue gasses})_{II} \quad 12$$

From equation 4, since input energy for system I (convectonal GTP) is greater than that of system II (GTP incorporated with CLC), then equation 12 shows that energy associated with flue gases in convectonal GTP will be more than energy associated with flue gases in GTP incorporated with CLC. If energy per unit mole of flue gases is constant, then it can be concluded that there will be more molecules of flue gases in convectonal GTP compared with GTP incorporated with CLC.

Case study II:

Considering the entire life cycle for energy resources and technologies suggests that improved efficiency reduces environmental impact during most stages of the life cycle. A clear example of this is considering a GTP at both early and late stages of its life cycle as follows:

System I: Convectonal GTP at its early stage of its life cycle

System II: Convectonal GTP at its late stage of its life cycle

Hence,

$$(\text{Input Energy})_I = (\text{Input Energy})_{II} \quad 13$$

$$(\text{Output Energy})_I > (\text{Output Energy})_{II} \quad 14$$

$$\text{Eff}_I > \text{Eff}_{II} \quad 15$$

If the energy balance in equation 6, 7 and 8 are consistent with these systems, then substituting equation 7 and 8 into 13, we get

$$(\text{Output Energy})_I + (\text{Energy loses to flue gasses})_I = (\text{Output Energy})_{II} + (\text{Energy loses to flue gasses})_{II} \quad 16$$

$$(\text{Output Energy})_I - (\text{Output Energy})_{II} = (\text{Energy loses to flue gasses})_{II} - (\text{Energy loses to flue gasses})_I \quad 17$$

From equation 14, since output energy for system I (Convictional GTP at its early stage of its life cycle) is greater than that of system II (Convictional GTP at its late stage of its life cycle), then equation 17 once again shows that energy associated with flue gases in Convictional GTP at its late stage of its life cycle will be more than energy associated with flue gases in Convictional GTP at its early stage of its life cycle. If energy per unit mole of flue gases is constant, then it can be concluded that there will be more molecules of flue gases in convictional GTP at its late stage of its life cycle compared with its early stage.

CONCLUSION

An overview of the negative effects of energy generation and consumption in our society, which include acid precipitation, ozone layer depletion and greenhouse effect were presented in this research. Energy conservation through improvement in energy efficiency was proven to be beneficial to the environment by a reduction of the carbon footprint released to the environment.

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