

Inquiry-Driven Thesis Paper

Nuclear Power Plant:

All things considered, Can nuclear power be beneficial to mankind? What is needed to make nuclear power more sustainable?



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Abstract

The purpose of this research is, considering the current trends which sustainability is considered to be one of important issue to mankind, to find possible ways to promote sustainability of nuclear power through analysis on the status, controversies and comparisons with other electricity sources.

By relative evaluating the sustainability of various energy sources, examination of sustainability is done on nuclear power. The methodology for measuring sustainability is to evaluate economic, social and environmental costs and benefits through these processes, this research investigated what are current and future challenges to nuclear power sustainability improvement.

Additionally, the policy recommendations to make nuclear power more sustainable are suggested based on the trends analysis and current and potential challenges nuclear power faces.

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1.0 Introduction

Nuclear power faces challenges

Most papers about nuclear power usually start with complicate data such as ‘there are certain number of nuclear powers in certain number countries and nuclear power has a large percentage of world electricity supply’. But for most people their primary concerns are mainly the issues of safety, price advance and power failure. Public concern over rising energy bills is at an all time high (UK Department of Energy & Climate Change, 2013). We cannot deny easily that nuclear power contributes much to us and there are many difficult problem which nuclear power causes in the world. Though nuclear power is one of biggest electricity supply, it has been under attack by many antinuclear groups. The challenges lie from economic to social matters. (Society, 1977)

Demand of electricity skyrockets

Global energy demand would not stop to increase and will be about 30 percent bigger in 2040 compared to 2010, as economic output more than doubles and prosperity expands across a world whose population will grow to nearly 9 billion people (Exxon Mobile, 2013) and over 1.3 billion people are suffering from lack of basic electricity (IEA, 2012). Therefore we cannot evade the permanent electricity supply problems with disregarding the facts

Important agenda : Sustainability

Environmental sustainability has become a core issue for human societies throughout the world. So sometimes we are forced to choose policies of many different fields in the perspective of sustainability (OECD, 2008). These trends let us think more about

sustainability of energy sources including nuclear power. But current energy's sustainable are threatened with population growth and energy demand increase. The decisions whether keeping nuclear or phasing out will be decided by each countries' authorities considering their economic, politic, environmental conditions and so on.

Efforts to find smart answers for energy problems

Nowadays, more and more academic and political interest has been concentrated on the matter of sustainable and we try to meet energy demands and to mitigate the threat of climate change – two of the 21st century's greatest challenges – there are major opportunities for expansion of nuclear energy in those countries that choose to have it. But those opportunities also pose complex and broad-ranging safety and security questions that must be addressed effectively (IAEA, 2008). However if we develop some guides for countries to help decide their nuclear power policy from the point of view of sustainability more and more countries could find it easier to identify their best options (Haluza-DeLay, 2011)..

1.1 Current status of nuclear power

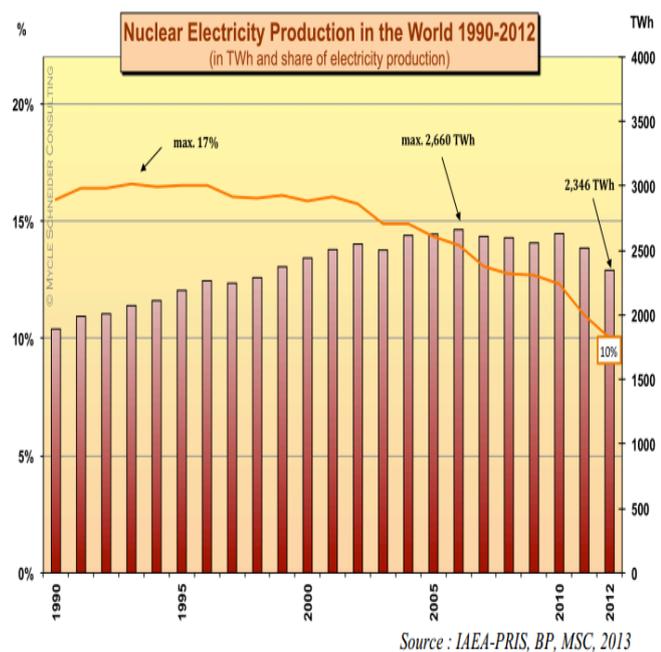
From table 1, we can see about 11% of global electricity is generated by 440 nuclear power reactors in 32 countries, there are 36 units currently under construction in 14 countries (IAEA, 2012). The first commercial nuclear power reactor began operation some 40 years ago, with a rapid expansion in reactor units taking place during the 1970s and early 1980s.

Figure 1 shows that nuclear electricity has produced electricity for long time and the peak time was around 2005,

Table 1. Nuclear power numbers

Important numbers about nuclear power (IAEA, PRIS, 2012)	
Total number	440
Operation	69
Average Age	28 year
Construction	36
Permanent shutdown	147
Total net Capacity	374.41GW
Total electricity supplied	2346.19TWH
World's electricity portion	11%

Fig.1 Nuclear Electricity production



From 1990 to 2012, nuclear power expanded steadily until 2006 and fluctuated with small range but the proportion of nuclear in world electricity production continues to decrease from 14% to 11% and after 2005, nuclear power lose its increasing state (Mycele Schneider, 2013). This may mean that the popularity of nuclear power to human may decline.

1.1.1 Positive opinions

Considering the view insisting from anti nuclear activist group such as Green Peace that, there is almost nothing positive thing about, s in nuclear but if we listen carefully what the nuclear industry points out says we can list up beneficial factors associated of with nuclear power. From their In their opinions, Nuclear power is clean, safe, reliable, compact, competitive and practically inexhaustible (Comby, 2006).

1. Nuclear power can produce electricity cheaper and more stable than others

Many governments and nuclear power companies generally agree that nuclear power is cost competitive with other forms of electricity generation (Facos, 2010).

Table 2. Brief comparison among electricity source (NEA, 2010)

Technology	Nuclear	Black coal with CCS	Large hydro-electric	Onshore wind	Solar photovoltaic
US cents/kWh	8.3-13.7	11.0	14.0-45.9	7.2-12.6	38.8-61.6

The fraction of nuclear fuel is smaller part of the operating cost with comparison to oil and gas. From Finnish study in 2000, doubling price of fuel results in electricity cost for nuclear rising about 9%, for coal rising 31% and for gas 66% (WNA, 2013). Nuclear has high energy security and the economic competitiveness of nuclear power can be enhanced more by allowing for CO2 emission costs. Moreover, nuclear power has is richness of nuclear fuel. We can get uranium from even seawater where 4 billion tons are dissolved (Lightfoot, 2006).

2. Nuclear power is clean and compact energy

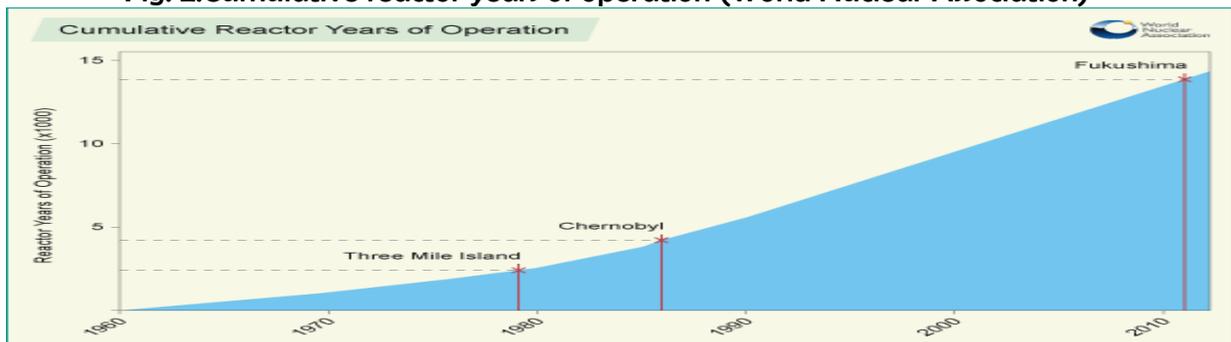
Most of all, nuclear power can make a boast of producing almost no carbon dioxide so nuclear power has the potential to continue to play a significant role in the effort to limit future GHG emissions while meeting global energy needs (Ebright, 2011). Nuclear power occupies smaller size land. Solar cells or wind turbine farm usually takes up as more than scores of times as large land as nuclear power plant's to generate same amount of electricity

(Energy.com). This implies nuclear power needs less land development and amazingly, 1g of uranium yields as much energy as a ton of coal or oil (Comby, 2006).

3. Nuclear power is safe enough to exist with human.

The safety of nuclear power can be proved by the records of half a century of commercial operation, with the accumulated experience of more than 12,000 reactor-years with only two serious. Fig 2 shows that the accumulated operation hour without accident is getting longer. Furthermore the safety improvement of nuclear power continues. Radiation risks from normal plant operation remain at a negligible level relative to natural and medical sources of public radiation exposure (Power, 2012).

Fig. 2. Cumulative reactor years of operation (World Nuclear Association)



4. Nuclear power devotes economy development

For example, South Korea is the 4th largest importer of oil in the world, the 3rd largest importer of coal. As South Korea lacks of natural resource, Korea has to import fossil fuels to meet energy demand for industries, transportations and residents (CHANAL, 2012). Nuclear power plants produce electricity domestically. Their capital and labor inputs are also provided domestically. With more than 90% of its inputs in terms of value sourced domestically, it can be considered a largely domestic source of energy and electricity. For this reason, many Korean concede that nuclear power contributed much to nation's economy growth with stable and cheap electricity supply. (Korea, 2011)

1.1.2. Negative opinions

The vanguard of anti nuclear power, Green Peace may complain they don't have enough time to list up negative sides of nuclear power. There has been enough numbers of nuclear power fatal accidents. At any time, an unforeseen combination of technological failures, human errors or natural disasters at any one of the world's reactors could lead to a reactor quickly getting out of control. Nuclear power has faced many challenges since its birth. The challenges and suspicious doubts became bigger and bigger. The weak points of nuclear power are safety, hidden cost, waste problem and causing social conflicts. Nowadays new problems emerge from new one such as finance and governance (Justin Alger, 2010).

1. Nuclear power cannot be free permanently from fatal accident risk

Unfortunately, nuclear power safety system cannot be perfect. Previous accidents prove this. Though different kinds of power plant have also fatal accident history, these accidents were just restrictive and temporary which differ from nuclear accidents which were permanent and extensive (Lelieveld, 2012). If nuclear power accident broke out, it could cause environmental consequences including the radioactive contamination of soil and water. For instance, In Fukushima accident in 2011, Tsunami was the main reason of accident (Hasegawa, 2013). Most people did not know new threat from natural disaster enough until Fukushima accident occurred

2. Nuclear power is hiding a great of hidden cost and dilemmas

Nuclear industry wins high praises with high economic competitiveness with saying that current production cost has already contained all kinds of cost enough. But the cost which they suggest might be just the number on their account books. Hidden costs can be waste

disposal and storage, decommissioning, public health and hidden subsidies (Ente, 2012). For example, actual decommissioning cost is usually more expensive than original budget (UNEP, 2012). Moreover, the way of permanent treatment to waste disposal is not fixed. No one assure how to deal with radioactive waste permanently (No2NuclearPower.org.uk, 2007).

3. Nuclear power can help proliferation of nuclear weapon

We can see many activities of international organization to forbid proliferation of nuclear weapon. North Korea as one of the autocracy country seeks to have nuclear weapons against most nations' wishes. To do this, North Korea tries to build nuclear plant to extract plutonium needed for nuclear bomb. During the operation of nuclear power plants, radioactive waste is produced, which in turn can be used for the production of nuclear weapons. In addition, the same know-how used to design nuclear power plants can to a certain extent be used to build nuclear weapons. Moreover, Nuclear power plant can be a target of terrorism (No2NuclearPower.org.uk, 2007).

4. Nuclear power has a bad social effects

Setting up a nuclear power plant in any region does not come without concerns and criticism from a wide variety of people. People in such regions fear the threat of being exposed to unusual levels of radiation. The main problem nuclear can destroy arm in arm community (Ramana, 2011). We can see many examples which residents were divided into two camps with different opinions. We can see improper energy policy could affect social relationship badly. For example, the BUN country in South Korea which attracted nuclear waste disposal facility experienced serious conflictions between residents and could not recover community spirit (institute, 2010).

1.1.3 Major Trends

Although nuclear power is currently a significant source of global electricity supply, there is no consensus about its future role. While nuclear power shrinks in most of Europe and in North America, it expands as an indispensable option in some Asian countries.

Since the Fukushima accident 2011, a many countries have decided reviews of their programs; some took steps to phase out nuclear power entirely, whereas others re-confirmed their expansion plans (WEC, 2011). After several years of the Fukushima event, The different nuclear polices in Germany and China provide a vivid comparison to reflect human’s dilemma in developing nuclear power (NEI, 2012).

Phase out - Germany

Germany has decided to the phasing out nuclear power by 2022.

The intention is for renewable energies’ share of power generation to rise from the current 17 percent of power consumption to at least 35 percent in 2020

Fig. 3 Phasing out plan of Germany

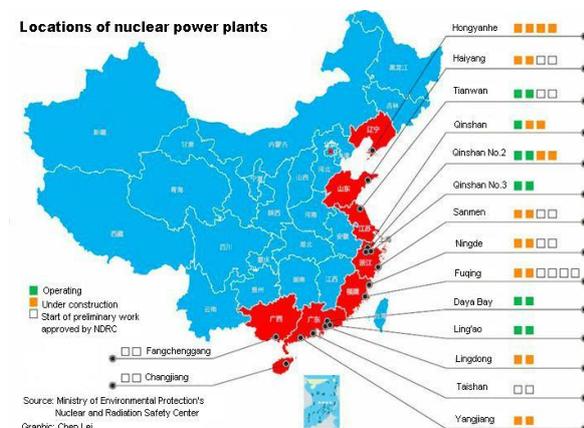


Fig. 4 Nuclear construction plan of China

Expansion - China

China has 17 nuclear power reactors in operation, 26 under construction.

China has a plan to increase in nuclear capacity to at least 58 GWe by 2020, then possibly 200 GWe by 2030, and 400 GWe by 2050.



1.2 Controversies on nuclear power

Discussing about nuclear power's merits and demerits is so complicated. We need to analysis pro and con's suggestions each critically. (Kaplan, 1980)

Table 3. Merit and Demerit of Nuclear power

	Opinions	Pro Nuclear	Anti Nuclear
Merit	Emits relatively low amounts of carbon dioxide (CO ₂)	Nuclear power emits almost zero carbon oxide.	Considering whole process of nuclear power plant, carbon dioxide from nuclear power plants is not small
	Low generating cost (economical)	Nuclear power plants produce more kilowatts than coal, oil and solar	Nuclear has too many hidden cost, so real cost is higher than expected
	High power in small volume	To meet high increasing electricity consumption rate, nuclear is very reasonable answer	Exorbitant construction costs may exceed a country's limit
	Rich fuel (reprocess)	In sea, there is unlimited Uranium and Used fuels can be reused by reprocess	Uranium is a scarce resource, its supply is estimated to last only for the next 30 to 60 years depending on the actual demand
	Small land and waste	To generate same amount of electricity, Wind and Solar farm need huge land to construct	Neighborhood of nuclear power is not suitable for resident and any human activities.
Demerit	Accident	Technologies is being developed and the probability of accident are going to be actually zero, multi safety systems including thick concrete wall can prevent accidents.	In US the last order for new plant was placed in 1970's
	Misuse (terror)	Nuclear power plant keeps higher security level and radioactive material is only one of many dangerous materials we can control	Radioactive materials can be stolen and used as weapon or terror device
	radioactive waste	There is no energy that is 100% clean	Currently there is no solution for nuclear waste
	Decommission	The cost of commission is already included in current cost	Current cost is not real cost and real cost can be double and triple in the end
	Conflict	Every power source cause conflicts among stakeholders	Conflicts from nuclear power are very serious and incurable

(PattersonWalter, 1986), (Comby, 2006), (Aref, 2010)

2.0 Sustainability and energy sources

Before we go into energy's sustainability, the definition of sustainability is needed. From World Commission on Environment and Development 1987, three essential aspects of sustainable development were stated as Economics, Environmental and Social (Harris, 2003).

Table 4. Core elements in sustainability

Economic	To produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectional imbalances which damage agricultural or industrial production
Environmental	To maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting nonrenewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.
Social	To achieve fairness in distribution and opportunity, adequate provision of social services including health and education, gender equity, and political accountability and participation.

2.1 Sustainability issue to energy

2.1.1. Definition of sustainability for energy

The World Energy Council's definition of energy sustainability is based on three core dimensions - energy security, social equity, and environmental impact mitigation. We can see that it is very similar to that of World Commission on Environment and Development.

Energy security can be explained as to meet demand without troubles. But energy security is a complex matter of supply and demand with unpredictable future. Secondly, Social equity is about accessibility and affordability of energy supply across the population. The third factor of energy sustainability is Environmental impact mitigation which encompasses many environmental issues such as carbon emission and waste disposal problems.

2.1.2. Possible Index to measure nuclear power sustainability

Table 5. Possible index to measure sustainability

Index	reasons
Price	Price to produce electricity is related with energy security and welfare, expensive electricity cannot support stable economy development
Efficiency	Efficiency is the rate of useful electricity with energy input. High efficiency can provide mass electricity with reasonable price
GHG emission	Lots of GHG emission cost us much money by climate change and climate change tend to be irreversible
Water use	Except photovoltaic, most powers need water to generate. More water needed means sort of limitations or consume natural resource
Fuel Availability	Except renewable energy, other power sources need fuels, If fuel is so restrict to use, the sustainability goes down
Limitations	Human needs electricity all over the world however every kind of power plant requires unique geography location. High restriction means low sustainability in construction and management.
Land use	Land use is different among power plant type. For example solar farm needs much space to generate same amount energy of fossil fuel or nuclear power
Social impact	Though certain type of plant has high efficiency and economical feasibility, if people opposite to that, that cannot be sustainable choice
Safety	Safety is very important factor which determine, Dangerous plant cannot go along with human.
Waste	Volume and toxicity of waste from power plant determine hidden cost
decommissioning	Every power plant has limited life time to operate and the difficulty and cost of decommissioning differs
Variability with fuel price	The fluctuation range of fuel price affect power plant's sustainability High fluctuation threatens the stability of energy supply
Risk of terror	If power plant is vulnerable to terror, it can be serious threat
People's perception	Regardless of actual performance if people hate certain kind of power plant with emotional reason, that cannot be sustainable power plant.

(Abouelnaga, 2010) (WYMAN, 2012) (FORATOM, 2012)

2.2 Comparison sustainability by relative evaluations

2.2.1 Method and limits

Many data varies from reference and groups, so the numbers might not be decisive for us to acknowledge the real status of nuclear power's sustainability. The measurement without extreme objective data which satisfy both pro and anti nuclear power groups can lose its worthy. Therefore this research tries to compare sustainability of energy sources by relative method before all. The aim of comparison is not to determine ranking but to check the status of nuclear power in the perspective of sustainability.

Table 6. Energy source sustainability comparison (Relative rank)

Index	nuclear	Coal	Gas	Photovoltaic	Wind	Hydropower
Less Price (Build, O&M)	Good (2)	Medium (5)	Medium (4)	Bad (6)	Good (3)	Good (1)
Stable supply	Good (1)	Good (1)	Good (1)	Bad (3)	Bad (3)	Bad (2)
Efficiency (Capacity Factor)	Good (1)	Good (1)	Good (1)	Bad (3)	Bad (3)	Good (2)
GHG emission	Good (1)	Bad (3)	Bad (2)	Good (1)	Good (1)	Good (1)
Water use	Bad (3)	Medium (2)	Medium (2)	Good (1)	Good (1)	Bad (3)
Fuel Availability	Medium (2)	Bad (3)	Bad (3)	Good unlimited	Good unlimited	Good Unlimited
Limitations	Medium (2)	Good (1)	Good (1)	Bad (3)	Bad (3)	Medium (2)
Land use	Good (1)	Good (3)	Good (2)	Medium (5)	Good (4)	Bad (6)
Social impact (hard to compare)	Bad	Medium	Medium	Good	Good	Good
Safety	Bad (5)	Medium (3)	Medium (4)	Good (1)	Good (1)	Good (2)
Waste volume	Bad (2)	Bad (4)	Medium (3)	Good (1)	Good (1)	Good (1)
Decommissioning cost	Bad (3)	Good (2)	Good (2)	Good (1)	Good (1)	Good (1)
Variability with fuel price	Good (2)	Bad (3)	Bad (3)	Good (1)	Good (1)	Good (3)
Risk of terror	Bad (3)	Good (2)	Good (2)	Good (1)	Good (1)	Good (3)
People's perception Support	Bad (4)	Bad (3)	Medium (3)	Good (1)	Good (1)	Good (2)
Total	7 bad	5 bad	3 bad	4 bad	3 bad	3 bad

(Pare, 2007) (Evans, 2010) (Ausralian Governmet Ministry of resource, 21013) (Ente, 2012) (IAEA, 2006) (OECD, 2010) (Ebright, 2011)

2.2.2 Result and implications

Evaluation from numbers of negative factors, nuclear power might have worst sustainability. But renewable powers also have many disadvantages to threats their sustainability. This means that improving sustainability is not sole challenge to nuclear power. This simple comparison can give us many implications to us. But if we enhance nuclear power's strength and reduce weakness, the absolute value of nuclear power's sustainability can grow up regardless of relative rankings. This is very meaningful, considering we have no alternative but to get along with nuclear power at least several decades.

In fact general evaluations to energy sources are losing effectiveness because every country has its own unique circumstance. For example Germany which announced phasing out nuclear power, consume less electricity from 2008 (indexmundi.com, 2013). So Catch up surging needs is not critical challenge to Germany. On the other side, China which has a fourfold increase in demand for 10 years (indexmundi.com, 2013), has to regard keeping energy security as its number one priority even though suffer consequence.

Thus the meaningful judgment to power sources can be obtained by not power source itself but overall circumstances. That is to say, Nuclear power can have enough sustainability in nation "A" while poor in nation "B". So we had better reject to say about nuclear power's general sustainability and talk about specific nation's nuclear power's specific sustainability.

2.3 Nuclear power's sustainability and challenges

2.3.1 Needs for improving sustainability

Nuclear power is just one of electricity energy sources. If nuclear power loses its competitiveness, it will be phased out gradually. This can give us clear implications why

nuclear power industry develops its sustainability. With the perspective of energy security, Nuclear power might be sorts of bridge energy between fossil fuel energy and renewable energy for a certain period of time. If it is, we should not save our efforts to make nuclear power more sustainable to earth and us. We cannot phase out every nuclear power plant actually within less than 50 years. Not all countries can adopt same policy of Germany. Dichotomous way of thinking which urges many nations to choose between expansion and closure might not be helpful for policy makers to overcome energy challenges. Therefore we need try to make existing, under construction and to be closed nuclear power plants more sustainable for us and our descendents.

2.3.2 Nuclear power's new challenges

Nuclear power may face two kind of challenges, one come from itself, the other comes from outside. As the old problems of nuclear power such as safety and waste which are so familiar to us, so new challenges should be listed up and prepared for suitable actions.

- Renewable energy technologies are being developed rapidly to cover weak points in economical feasibility so nuclear power may be inferior to them soon (IEA, 2011)
- Nuclear reactors sold to states without expertise, infrastructure, safety & security culture, this can cause huge catastrophe (Findlay, 2010)
- Innovation in nuclear power governance to solve problems in security (Findlay, 2010)
- Nuclear power grow older but related R&D developments are too slow to catch up needs in time (MIT, 2009)
- Cannot expect same level of subsidies which are received before (Koplow, 2011)
- Need long time to recover degeneration of public image by continuous accidents (NEI, 2013)

3.0 Improvement Directions

Public policy including energy field mainly depends on surrounding environment including political system, preference of mass people, economic scale, etc. Specific country's nuclear power policy has different requests and constraint conditions. For example, United States which has plenty of natural resource and less than 2% of electricity demand growth can choose flexible policy among many options while new rising economy developing countries with deficiency of natural resources such as China and South Korea have restricted options (FORATOM, 2012). Though matters are different in nations, the common improvement directions to nuclear power can be suggested.

3.1. More transparency in policy decision

The era of internet has changed much in public policy's environment. People can access professional information though online with easy. More and more people are interested in public policy and want to take part in the process of public policy decisions in varied ways (Roy, 2008). But reality is opposite to people's wish. Anti nuclear power groups criticize that few numbers of expert groups decide important nuclear power policy and ask people to just follow or accept their decisions (Sovacool, 2011). The reason why nuclear power policy is rather exclusive may be come from the complexity of technology, restricted stakeholders such as companies, government and investors. People want to have more confidence about nuclear power. Nuclear has many strong beneficial points with weak ones just as other electricity energy sources do. Most countries selected nuclear power from not unconditional preference but their needs calculated in details. Without frankness of nuclear power and enough understanding of people, nuclear power plants cannot avoid to be treated as ugly duckling (Weart, 1991).

3.2 Additional sustainability of nuclear power outside nuclear power

As technology development and financial investment have their limits, Nuclear power has an insurmountable limit to develop its absolute sustainability. However the role and evaluation of nuclear power can vary with broadening boundaries. There are too many roles for nuclear power to contribute to human by eliminate poverty, water shortage, disease and jobless (Vergragt, 2006). Sustainability evaluation which is focused on nuclear power itself can overemphasize limits and flaws of nuclear power while more comprehensive view can highlight comparative advantages to other electricity source. For example, Nuclear power is considered to be one of practical facilities for seawater desalination compared with other kinds of facilities (Kupitz, 1995). If we take new possibility of application for human being into consideration, more new policy recommendations can be suggested to achieve higher sustainability of nuclear power by governments or industries.

3.3 Stronger cooperation with other energy sources

When every country has its own optimum energy portfolio to meet needs, nuclear power can also maximize its value. At a glance, each electricity source seems to be competing with each other but their relations can be complementary. For example, only when nuclear or fossil power supply takes responsible of power basis, renewable energy can be connected to grids and mixed with other sources. If the concept of intermittent energy source is accepted every energy source has each role (Ambec, 2010),. The fossil fuel and nuclear power has more time to have reasons for the existence and the renewable power also has time to have more economic feasibility. Currently nuclear power has so many opponents but situations can reverse if green house gas emission problem worsen. Nuclear power could take less criticism. Helping other electricity source have more sustainability can result in enhancing overall sustainability of nuclear power finally.

4.0 Policy recommendation

4.1 Construct better governance over nuclear power

Current status and Challenges

The core of current nuclear power's global governance is IAEA, IAEA has shown many successful activities to member countries. But the environment has changed continuously and request to enhance coping with government agencies or non government agencies in existing nuclear energy states. Safety and non proliferation are regarded as primary mission in times past however more and more complicated missions are allotted to IAEA (Justin Alger, 2010). As nuclear powers keep growing older. The hidden problems in early time, decommissioning, and waste disposal and life extension are confronted with us. The authority of organization comes from problem solving ability. So IAEA should enhance new supports service for its members in troubles.

Improvement direction

- Response to new needs IAEA members by diversification and specialization
- Enhance IAEA abilities by cooperation and agreement of members

Feasible actions

- IAEA designs new programs to shift nuclear power advanced countries' technologies and experience to rising nations
- Secure funds to help IAEA to support technical and consulting services
- Strengthen responsibility of advanced countries to solve nuclear power dilemmas
- Study or suggest realizable plans more aggressive about regional waste disposal or co-owned nuclear power plant across boundaries

Expectations

Cost saving and credibility increasing of nuclear power, enhancing IAEA's status

4.2. Reinforce democratic procedure in nuclear power policy making of government

Current status and Challenges

People have vague worries about GMOs and vaccines, the reasons come from fear of unknown technologies. Nuclear power has same problem. Whenever people hear the accident of nuclear power, the fears become bigger. The other aspect of fear is that danger which people did not choose seems to be bigger than that of people chose (Jogalekar, 2013). Nuclear power policies are actually made by limited technocrats, so most people including residents near nuclear power plant tend to be excluded in policy making. It is very hard for all people to take part in policy making but there can be many options to improve participation. As we assume more responsibility for our choices, if we develop our policy making more participatory nuclear power policy decision, we can expect more responsible and future oriented decisions.

Improvement direction

- Extend participation of people in energy policy
- Develop medium and long term plan affected by public opinions
- Do not regard nuclear power as indispensable one

Feasible actions

- Set a nuclear power phase out plan of each countries, if possible and analyze the impact on energy security and lives of people
- Adduce options of energy portfolios in more than 10 years to public, Options include electricity costs and balance of energy, Build new policy decision system which the results of polls can be reflected on national energy master plan

Expectations

The satisfaction to energy policy will improve regardless of public's options and government can avoid criticism of dictatorship of the energy policies.

4.3. Support renewable investment and Promote energy saving with public policy

Current status and Challenges

Global energy demand continues to increase by huge rate, it comes from industrialization, population increase and changes of lifestyle. However we cannot supply limitless electricity human needs. This made us think about how we can manage demands of electricity. Considering supply and demand curves, Increasing demand and limited energy resources make electricity more expensive (Ausralian Governmet Minisry of resource, 21013). Energy saving can contribute much for sustainability with less use of natural resource. As you know, renewable energy efficiency and economic feasibility is not good compared with fossil fuel and nuclear power. Because of many vulnerable point of renewable energy, most country and generating companies are reluctant to invest on renewable power plants (OECD N. , 2012). If nuclear power helps renewable energies to overcome their weak points, nuclear power could gain additional sustainability points.

Improvement direction

- Impose responsibility to invest renewable energy on nuclear power expansion by enacting of law, this needs co-work by government and national assembly
- Save electricity in resident, industry and transportation with government's policy

Feasible actions(By government or law making organ)

- By imposition of tax and coordination of subsidy, renewable energy gets more supports from nuclear power.(for example "Renewable Portfolio Standard")
- Act strong administration of demand on electricity with energy saving policies

Expectations

Mitigate low economic feasibility of renewable energy and relieve pressures from increasing electricity demand with energy saving

4.4 Introducing a representative evaluation of nuclear power's sustainability

Current status and Challenges

The role of evaluation of something is to correct and develop, so there may not be any dissent to improve nuclear power's sustainability. As nuclear power is being requested to increase sustainability (IAEA, 2006), we need not further reasons why we have to introduce systems to evaluate sustainability of nuclear power. However important thing is how effective and realistic the evaluation is. Unless evaluation has power of execution and follow up steps, Evaluation might be meaningless. Many evaluations are performed by various institutes now but the effect is questionable. We might need to expand the meaning of sustainability to nuclear power from security and safety to most significant concept which embraces almost all.

Improvement direction

- Impose more important roles on IAEA about sustainability by its members
- Sustainability evaluation is institutionalized in international agency

Feasible actions

- Redefine the concept of sustainability of nuclear power, enlarge the meaning from safety to sustainability itself by international organizations such as IAEA and UN
- Conduct sustainability assessment over nuclear power policies of countries have nuclear power by refutable global organization (IAEA, OECD)
- Need to expand and reorganize department which deal with sustainability issues in IAEA and other organizations
- Provide consulting service to improve sustainability with IAEA member countries

Expectations

Get clearer concept sustainability of international organizations over nuclear power. Build more efficiency systems to conduct sustainability tasks in international organizations

4.5 More frank with hidden costs of nuclear power

Current status and Challenges

Nuclear power cannot be free from suspicious eyes on hidden costs. To make matters worse, nuclear power has not only one but several hidden costs. However nuclear power may need not be shy on these problems because every energy source has its own hidden costs (Geoff Keith, 2012). All hidden cost of energy sources is variable according to method of calculations and assumptions. The main reason for nuclear power to lose its credibility from people may be from not hidden cost but deviousness (OECD, 2010). If nuclear industry does its best to clear nuclear power's hidden costs, most people would not stand by nuclear side any more.

Improvement direction

- Active participation of evaluation nuclear power
- Keep a modest attitude to criticism from anti nuclear power group

Feasible actions

- Carry out regular calculation about environmental costs with at least neutral figures, If possible, IAEA or OECD can have an important role in this process.
- Analysis the result of subsidies from government, compare with other sources and make a disclosure of results by IAEA or OECD
- Make a plan about how to reduce hidden or real costs through R&D, cooperation with countries(prepare for subsidy reform in future, this works done by each nation)

Expectations

More frankness from nuclear power international organizations can drive nuclear power to do more efforts to reduce hidden costs and people can believe nuclear power policies more.

4.6 Enhance cooperation of grids through nations

Current status and Challenges

Commercial nuclear power plants has bigger capacity over 1000 MW than small fossil fuel or renewable power plants but this can reduce nuclear power's position and economical feasibility. That is the main reason why nuclear power is not suitable to countries which have small amount of electricity demand. But if nuclear power can break up spare electricity efficiently to other regions, the defect becomes a different story. Combined grid can help every electricity source to be more competitive. Integral grid can transmit electricity from various sources according to each peak times. So we need to concentrate on the EU's "super grid plan which connects with regional small grids (Vea, 2006).

Improvement direction

- Make more flexible policies by diversification with a aid of grid between nations
- Make more efforts of nuclear power to take part in super gird plan by international organizations such as UN and World Bank

Feasible actions

- The IAEA can work with states to encourage the establishment of shared regional nuclear plants. These can help countries whose electricity demand or power grid is too small to justify their own large base load plants to access nuclear energy
- IAEA, UN or World Bank helps underdeveloped countries to seek their most appropriate energy type to choose including nuclear power and grid problem.

Expectations

Energy security matter is very complex and hard to be equal for stakeholders. But if neutral and trustful agencies suggest certain plan, it can be helpful to countries in the end.

4.7. Reinforce communication between pro and anti nuclear groups

Current status and Challenges

The conflicts or battle between pro and anti nuclear groups seems to be going steadily downhill. Nowadays the controversies show no sign of ending. Green peace, most prominent active and aggressive anti nuclear group attacks and invade nuclear power area illegally, nuclear power companies criticizes Green peace's activity as criminal act against that. But the problem is that the outlook of wars about nuclear is getting darker. We cannot see any hopeful compromise or mutual understandings. Both groups are even use abasements and ridicules in public address (Vidal, 2012). Considering that conversations exists among nations at war, Is it impossible for opposite nuclear opinion groups to have constructive talks? Though it seems to be naïve thinking without awareness of a reality, improvement is needed within arguments of nuclear power policies.

Improvement direction

- Provide a forum for conversation and neutral zone for free talking
- Start work together about main and trivial issues

Feasible actions

- Hold a regular general meeting which all opinion groups attend, the meeting can be arranged by neutral academy institutions
- Carry forward with co-works such as publish a white paper about nuclear power and make a thorough investigation into nuclear power's conundrum

Expectations

Mutual understanding can be raised and controversies between them can be change from to exclusive into constructive

4.8. Sufficient investment to nuclear power safety

Current status and Challenges

The Fukushima–Daiichi accident of March 2011 caused deep public anxiety and raised fundamental questions about the future of nuclear energy throughout the world. Though nuclear power plant is equipped with safety. They cannot obstruct all accidents which come from natural disaster such as tsunami and earthquake (Commission, 2012). Many scientists and engineers insist that current safety system of nuclear reactor is enough. However the perceptions of the dangers come from the fuel cycle associated with nuclear power generation and radioactive waste transportation and disposal is hugely different from that held by residents within the nuclear infrastructure (Ballard, 2009)

Improvement direction(By Government)

- Break from scientific basis while analyzing degree of risk and consider normal people's perception.
- Invest in advance on safety and give additional point afterward regulation

Feasible actions

- If resident want to reinforce excessive safety facilities, nuclear power generating company try to accept request and government help them by possible subsidy (In South Korea, Gov extended sea wall over maximum height of a wave)
- To make up for excess investment on safety and government think about giving additional beneficial point over life extension approval to avoid waste of resource

Expectations

Can expect more comfortable feeling of residents and prevent massive hazard from unexpected accidents which will be connected to increase of sustain ability

4.9. Start new aid projects with nuclear power technology

Current status and Challenges

The estimation and evaluation of nuclear power seems to be restricted only to commercial nuclear power plant. But nuclear power technologies can be utilized in various fields. Nuclear energy is used in several non-electric applications, including seawater desalination and district heating. It has the potential for expanded use in desalination, in extracting non-conventional oil, in co-generation with coal and in hydrogen production for transport (Majumda, 2002). To compensate sustainable loss from waste, safety and cost increasing, Nuclear power need to expand their role in saving lives, growing crops and providing jobs in the developing world (IAEA, 2008)

Improvement direction

- Respond aggressively to pressing global crises in food security, health and the availability of drinking water through the use of nuclear techniques
- Develop small-medium size nuclear power technology and project

Feasible actions(By international organization such as IAEA, UN, World Bank)

- Raising fund through international organization's share of the expenses for the projects related with nuclear technology to help countries in need
- Facilitating small-medium size nuclear power reactor R&D and seawater desalination project in water and electricity deficient country with international aid

Expectations

Nuclear reactor can help billions of poor people need energy and other life-saving and job-creating technologies

Flagship project can prove the superiority of nuclear power by supply water and energy

5.0 Conclusion & Further Research study

The aim of this research is to ask for rethinking over dichotomy about nuclear power's value. Current threats such as population growth and greenhouse gas emission to sustainable development are the realities. Moreover, nuclear power has many original disadvantages and limits of sustainability development to be criticized by anti nuclear power group. But unfortunately we do not have any clear alternatives. On balance, the important thing for us to find is not to develop sustainability of nuclear power itself but that of the entire globe. These reasons drive us to expand our horizons outside of nuclear power. Enhancing the competitive of nuclear power is the basis of the increasing nuclear power's sustainability but if we focus just on nuclear power itself to upgrade sustainability, we would face the limitations and be frustrated. These can be the primary reason to do more efforts to develop nuclear power's sustainability by various applications of nuclear power techniques and collaborations with other electricity source.

Further study can be a research about how to upgrade sustainability evaluation methods. To assess and correct nuclear power's sustainability for specific country we need a yardstick of judgment. Inventing and developing new index will be needed to support sustainable energy policy decisions. Higher sustainability of energy policy can be obtained by cooperation with energy sources and different nations. So new concrete nuclear power programs for people and countries in difficulty are need to be established with global cooperation.

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