THE EXTERNALITY STUDY OF INDONESIA NUCLEAR POWER PLANT

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ABSTRACT

THE EXTERNALITY STUDY OF INDONESIA NUCLEAR POWER PLANT. It has been calculated the externality cost of Nuclear Power Plant on Muria Peninsula, Jepara, Central Java. In this study is used the KSN-1000 (the *Korean Standard Nuclear, Pressured Water* Reactor 1000 MWe) as reference. Meanwhile, for environmental data, it is used the data from Tricastin nuclear power plant. NukPacts Model is used in this study to calculate and evaluate the externality cost of nuclear power plant. The externality study consider valuing the human health effects of routine atmospheric releases from nuclear power plant and the external costs of nuclear accidents. The valuation of health effect in the externality study is carried out by a Value of Life Year Lost (VLYL) approach. The impact of routine atmospheric releases is about US$ 5.60E-05 per-kWh. Meanwhile, external cost from nuclear accident, nuclear water impact and radioactive waste disposal are expressed in US$ 2.69E-06 per-kWh, US$ 6.11E-09 per-kWh and US$ 2.54E-06 per-kWh respectively. So, the total *externality cost (total damage cost)* of NPP (1000 Mwe) is around US$ 6.12E-05 per-kWh.

ABSTRAK

STUDI EKSTERNALITAS PEMBANGKITAN LISTRIK TENAGA NUKLIR DI INDONESIA. Telah dilakukan perhitungan biaya eksternalitas Pembangkit Listrik Tenaga Nuklir di Semenanjung Muria, Jepara, Jawa Tengah. Dalam studi ini digunakan referensi pembangkit nuklir Korea jenis Pressurized Water Reactor dengan daya 1000 MWe (KSN-1000), sedangkan untuk data lingkungan, digunakan referensi pembangkit nuklir Tricastin. Perangkat lunak yang dipakai untuk perhitungan dan evaluasi biaya kerusakan lingkungan akibat pembangkit nuklir adalah Program NukPacts. Studi yang dilakukan mempertimbangkan penilaian efek kesehatan manusia akibat operasi rutin PLTN dan biaya eksternal akibat kecelakaan nuklir. Penilaian terhadap dampak kesehatan dalam studi eksternalitas digunakan pendekatan *Value of Life Year Lost* (VLYL). Hasil perhitungan biaya eksternalitas akibat emisi dari operasi rutin PLTN ke atmosfer adalah sekitar US$ 5.60E-05 per-kWh, sedangkan biaya eksternalitas akibat kecelakaan nuklir, akibat dampak lingkungan melalui air dan penyimpanan limbah radioaktif, masing-masing adalah US$ 2.69E-06 per-kWh, US$ 6.11E-09 per-kWh and US$ 2.54E-06 per-kWh. Jadi total biaya eksternalitas (total biaya kerusakan) akibat PLTN berdaya 1000 Mwe adalah sekitar US$ 6.12E-05 per-kWh.

1. INTRODUCTION

1.1. Background

In order to successfully support the national development program in Indonesia and in consideration to the changes of global strategic environment, an integrated and solid energy policy has been set up.

At present, Indonesia does not have any NPP. The introduction of NPP in Indonesia is not only to reach an optimum energy mix considering costs and environment, but also to relieve the pressure arising from increasing domestic demand for oil and gas. Thus, the role of Nuclear Power Plants is clearly to stabilize the supply of electricity, conserve strategic oil and gas resources and protect the environment from harmful pollutants as a result of the use of coal or fossil fuels. This concept is exactly congruent to the national energy policy which stresses diversification, conservation and environmental awareness in energy supply development.

According to the study report of energy suplly analysis of the "Comparative Assessment of Different Energy Sources for Electricity Generation in Indonesia (INS/0/016)" by using Markal Program (Market Allocation) that considered the crisis in Indonesia, shows that the introduction of the first nuclear power plants is in the year 2013 (Case IEA1003) to the Java-Bali electric system represents an optimal solution of power configuration. But if using the Case IEA1002, the introduction schedule of the first NPP will be postponed until the year 2018[1].

The externality study of power generation plant is a part of the Comparative Assessment. One of the power generation plants is nuclear power plant (NPP), therefore, the NPP externality study has to be studied. For this study, the nuclear plant type of KSN-1000 (the Korean Standard Nuclear, Pressured Water Reactor 1000 Mwe, as reference) that's assumed operation in Ujung Lemahabang, Jepara, Central Java, will be observed.

1.2. Objective

The objective of this study is to calculate the externality cost of nuclear power plant. The externality study consider valuing the human health effects of routine atmospheric releases from nuclear power plant and the external costs of nuclear accidents. Routine releases from nuclear facilities fall into three main categories: (1) air emissions into the atmosphere; (2) liquid discharges into the water (in this case, we consider the coastal); and (3) waste disposal in the ground.

2. METHODOLOGY

This study use methodology as follows:

a. Study of literature that related the externality aspect of nuclear power plant.
b. Data collection and processing for fulfilling input data requirement for NukPacts Model.
c. Calculating and evaluating the nuclear external costs by using NukPacts Model.

The methodology is presented for quantifying and valuing the adverse effects on human health resulting from the routine release of radionuclides to the atmosphere from nuclear power plant and from the nuclear accidents. In this study, it is used NukPacts Model to calculate the externality cost of nuclear plant. This model consists of program to valuing the human health effects of routine atmospheric releases from nuclear power plant and program to calculate external costs of nuclear accidents.

3. DESCRIPTION OF NUCLEAR POWER PLANT

Although the reactor type to be introduced in Indonesia has not been decided yet, it will be a Light Water Reactor (LWR). This study uses the KSN-1000 type (the Korean Standard Nuclear, Pressured Water Reactor 1000 Mwe) as reference. For environmental data, it is used the data from Tricastin nuclear power plant. The data are included the nuclear power plant candidate type, dispersion, data of the direct inhalation of radionuclides in the air, data of the external irradiation from radionuclides immersed in clouds, data of the external irradiation from deposited radionuclides, data of the ingestion of radionuclides in agricultural products, data of the number of fatal and non-fatal effects from nuclear accident, etc.

3.1. The Nuclear Power Plant Candidate for the Study Case

The technical data of KSN-1000 Nuclear Plant that used in this study are presented at bellow[2]:

- Name of NPP reference: KSN-1000 (the Ulchin Nuclear Power Plant Unit 3).
- Type of power plant: pressurized water reactor (PWR).
- Period of reactor operation: since 1998.
- The nuclear steam supply system (NSSS) is designed for a total thermal power output of 2,825 MWt.
- Fuels: low-enriched uranium oxide UO_2.
- Nominal capacity: 1000 MW electric net.
- Capacity factor: 0,75 (assumption).

3.2. Routine Atmospheric Releases From Nuclear Power Plant[3]

Routine releases from nuclear facilities fall into three main categories: (1) air emissions into the atmosphere; (2) liquid discharges into the water (in this case, we consider the coastal); and (3) waste disposal in the ground.

3.2.1. Air Emissions of Radiation into The Atmosphere

There are four priority pathways by which the atmospheric release of radionuclides may adversely effect human health. These are through:

- the direct inhalation of radionuclides in the air;
- the external irradiation from radionuclides immersed in clouds;
- the external irradiation from deposited radionuclides; and
- the ingestion of radionuclides in agricultural products.

The scope of the assessment has a spatial and temporal dimension. The spatial scope, based on a radial grid, is divided as follows:

- zero to 100 km from the emission source (the ***local*** scale);
- 100 to 1,000 km from the emission source (the ***regional*** scale);
- greater than 1,000 km from the emission source (the ***global*** scale).

The transport of radionuclides in the atmosphere for the local area assessment (i.e. 0 to 100 km from the source) is calculated using the simplified Gaussian-plume model.

The average wet and dry deposition velocity is taken as 5.00E-3 metres per second (CEC, 1995, p 29).

The methodology used to estimate the ***total collective dose*** occurring in the 'local' public population (i.e. inhabitants residing within 100 km of the emission source) *via* each of these pathways is outlined below:

- Population at Risk
- Inhalation of Radionuclides in the Air
- External Irradiation from Radionuclides Immersed in Clouds
- External Irradiation from Deposited Radionuclides
- Ingestion of Radionuclides in Agricultural Products
- Ingestion of Tritium and Carbon – 14
- Global Impacts, for a few radionuclides, including tritium (H – 3), Carbon – 14 and Krypton – 85, however, may become widely dispersed throughout the global atmosphere and oceans.

3.2. Nuclear Power Plant Accidents Data[4]

In this study, the external costs of nuclear accidents will be analysed. Therefore, this study needs data, such as: country where plant is located, number of fatal and non-fatal effects (number of fatal cancers, number of severe hereditary effects, number of non-fatal cancers, number of early diseases), population and number relocated and evacuated, Value of a Statistical Life, Value of Non-Fatal Injury, Total Food Ban costs, Total Evacuation costs, Probability of accident, Indirect Costs as % of Direct Costs, Average Individual Wealth, Coefficient of Relative Risk Aversion, and Annual Production (for this study is used 6.57 TWh as annual production of 1 unit Nuclear Power Plant of KSN-1000 MWe).

4. SITE DESCRIPTION [5,6,7,8,9,10]

The Republic of Indonesia is located in Southeast Asia on an archipelago of more than 17,000 islands astride the equator (see Figure 1). Meanwhile, Ujung Lemahabang is the selected site for siting the first NPP in Indonesia that's located in the north coast of the Muria Peninsula (Figure 2). Site coordinate is about 6°26' South Latitude and 110°47' East Longitude. The size of the referred site is approximately 3 km wide in east-west direction and 2 km wide in north-south direction.

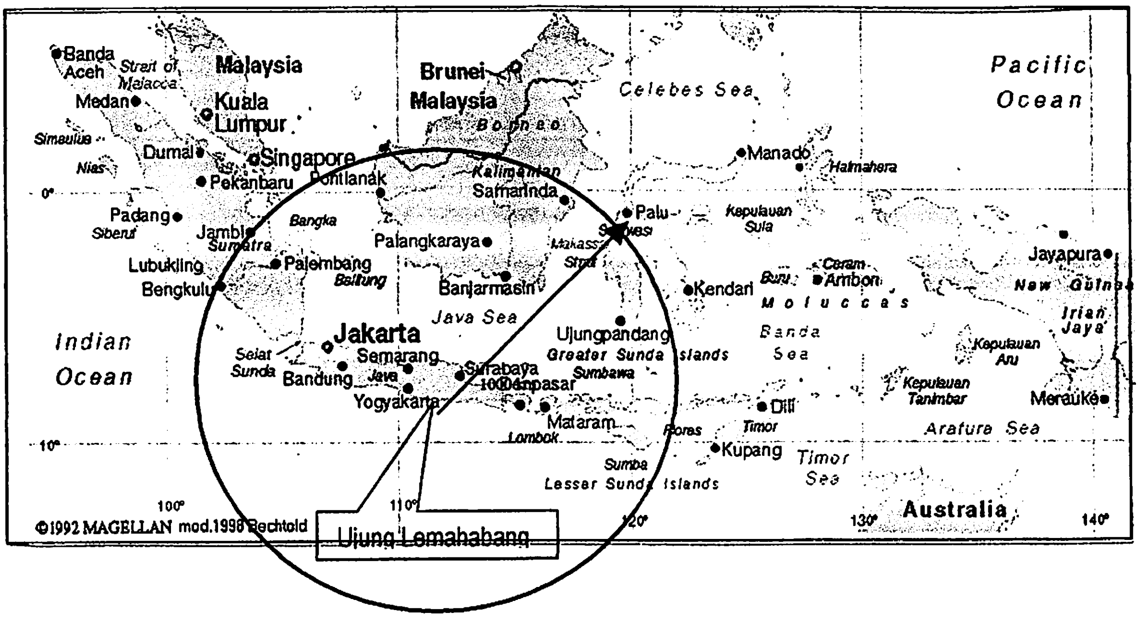
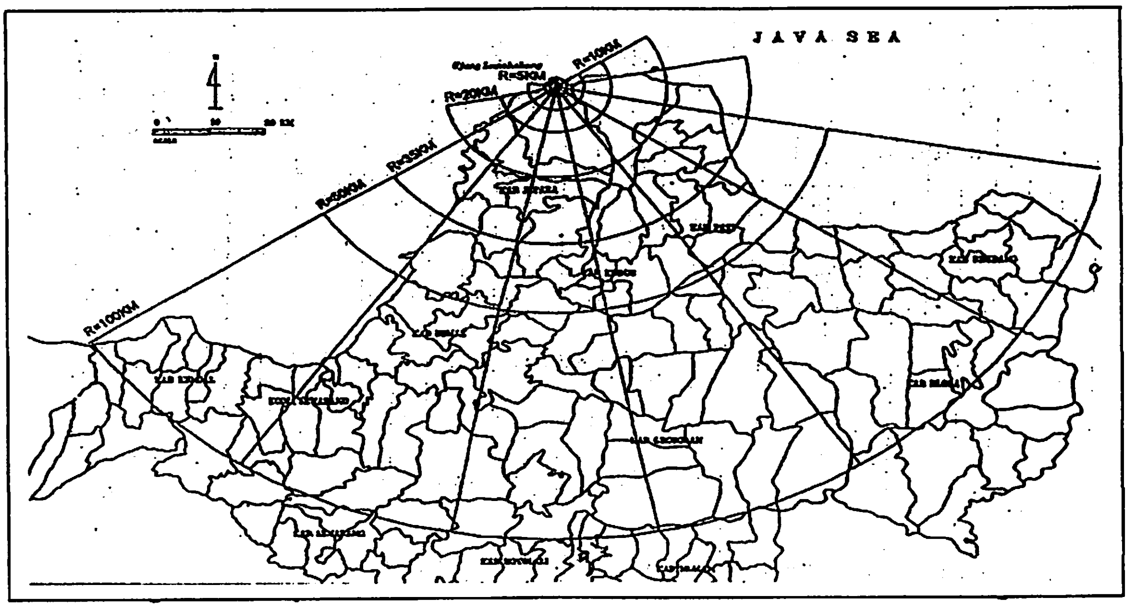


Figure 1. Map of Indonesia (Annular Sector in Ring 1000 km is Regional Area)

Ujung Lemahabang site belongs to the village (Desa) Balong, the district (Kecamatan) Kembang, the regency (Kabupaten) Jepara. Ujung Lemahabang is about 30 km from Jepara, and 120 km from Semarang, the capital of Central Java Province. Most part of the site lies in the plantation area owned by *PTP IX Nusantara*, a state owned company. In this site, the construction of NPPs with a total capacity of 7000 MWe can be accommodated.



The Muria Peninsula is located at the central part of the north side of Java Island (see Figure 2). It stands out into the Java Sea from the base of Kudus, located about 50 km north-east of Semarang. This peninsula tip is about 50 km wide in east-west direction, about 45 km wide in north-south direction, and its area is approximately 3,000 km2. In this peninsula there are Kabupaten (Regency) Pati in the east, Kabupaten Jepara in the west and Kabupaten Kudus in the south.

Table 1. Wind Direction Fraction.

Wind Direction	Fraction	Procentage
Wind Blows from South to North Direction (consists of S+SSW+0.5SW+SSE+0.5SE)	3.82E-01	38.2 %
Wind Blows from West to East Direction (consists of W+WSW+0.5SW+WNW+0.5NW)	1.90E-01	19.0 %
Wind Blows from North to South Direction (consists of N+NNW+0.5NW+NNE+0.5NE)	1.75E-01	17.5 %
Wind Blows from East to West Direction (consists of E+ESE+0.5SE+ENE+0.5NE)	2.53E-01	25.3%
Total	1.00E+00	100.0 %

Note: *S = wind blows from South to North direction* *N = wind blows from North to South direction*
W = wind blows from West to East direction *E = wind blows from East to West direction*

Average annual wind speed at Ujung Lemahabang is about 5.4 *m/s* (anemometer height h=40m), and the average of ambient air temperature is about 301.6°K.

Fraction of wind direction blows from South to North, from East to West, from West to East and from North to South are about 38.2%, 25.3%, 19% and 17.5% respectively (see Table 1).

4.1. Demography

The population number and population density within the radius 100 km around the Ujung Lemahabang site (local area) are 8,033,635 person and 256 person/km2, respectively.

Meanwhile, absolute population and Population density in the regional area (within the radius 1000 km around the Ujung Lemahabang site) are 155,050,065 person and 49 person/km2, respectively. But, the regional population for nuclear accident input data should consider the meteorology aspects, especially the wind direction. By considering the fraction of wind direction (see Table 1 above), the regional population (for nuclear accident) is about 34,938,564 person (see Table 2).

Table 2. Regional Population (for NukPacts Input Data) by Consider the Wind Direction

Population Description	Population	Fraction of Wind Direction	Population (impact by considering Wind Dir.)
Population within the North section (area section from 315° until 45°) (area including Kalimantan (West, Cental & South), East Malaysia)	9,011,765	0.382	3,438,626
Population within the East section (area section from 45° until 135°) (area including East Java, Bali, NTB, NTT, East Kalimantan, South Sulawesi)	44,808,758	0.190	8,531,538
Population within theSouth section (area section from 135° until 225°) (area including Central Jawa and DI Yogyakarta)	33,965,967	0.175	5,939,318
Population within the West section (area section from 225° until 315°) (area including Jakarta, West Jawa, Banten, Lampung, Bengkulu, South Sumatera & Jambi)	67,263,576	0.253	17,029,082
Total	155,050,065	1	34,938,564

4.2. Agriculture Production

Six categories of food products (agricultural products) are considered, namely cattle (beef), sheep (lamb), grains (cereals), green vegetables, root vegetables and milk. The density of that products in the local area is presented in Table 3.

Cattle category consists of cattle, buffalo and pig, with the product density is about 0,72 ton/km^2. Meanwhile, sheep category consists of sheep, goat, poultry and rabbit, that the product density is about 1.277 ton/km^2.

Grains category (paddi, corn, peanuts, soyabeans, small green pea) has product density about 95.91 ton/km^2.

Green vegetables category (shellot, garlic, cabbage, chili, tomato, y. bean, beans, cucumber, and fruits) has product density about 10.55 ton/km^2. Meanwhile, Root vegetables category (cassava, sweet potato, potato, carrot) has product density about 14.54 ton/km^2. And milk category (milk and eggs) has product density about 1.56 ton/km^2.

5. ASSUMPTION

Threre are some assumptions that used in this study, i.e.:

a. Estimation of some regencies area percentage within annular sectors in ring 100 km (local area), such as regencies (*kabupaten*): Grobogan, Rembang, Kendal, Blora, Semarang, Boyolali and Sragen.
b. Estimation of some provinces area percentage within annular sectors in ring 100 km (regional area), such as provinces (*propinsi*): Nusa Tenggara Timur, Bengkulu, South Sumatera, Jambi, East Kalimantan, South Sulawesi and East Malaysia.
c. 1 ton milk = 1000 litre.
d. 1 Euro = 0.94 US$ (CNN, 12 June 2002).
e. Grains category consists of paddi, corn, peanuts, soyabeans, small green pea.
f. Root vegetables consist of cassava, sweet potato, potato, carrot.
g. Green vegetables category consists of shellot, garlic, gabbage, chili, tomato, yardlong bean, beans, cucumber, fruits.
h. Fruits consists of mango, rambutan, lanson domesticum, klengkeng, star fruit, durian, banana, salak, orange, pine aplle, papayas (in this study, fruits is included in the green vegetables category).
i. Cattle category consists of cattle, buffalo and pig.
j. Sheep category consists of sheep, goat, poultry and rabbit.
k. Milk category consists of milk and eggs.
l. Etc.

Table 3. Agricultural Products Density

Categories of Agricultural Products	Density of agricultural *(ton product per km²)*
Cattle (beef)	0.72
Sheep (lamb)	1.277
Grains (cereals)	95.91
Green vegetables	10.55
Root vegetables	14.54
Milk (dairy cows)	1.563

6. RESULT AND ANALYSIS

6.1. Result of Impacts of Routine Atmospheric Releases

Table 4 shows the estimated total health effects for each impact pathway at the local and regional scale, and the total of both. Total priority impact pathways for local, regional and total of both are 2.46E-01, 4.34E-02 and 2.89E-01 man Sv per year respectively. Therefore, the health effects at the regional scale are about 15 percent of the total local and regional scale impacts, which is consistent with the results of CEC (1995).

Table 4. Impacts of Atmospheric Releases: Total Collective Dose

	Local	Regional	Local + Regional	Unit
Priority Impact Pathways:				
Inhalation	4.19E-03	7.39E-04	4.93E-03	(man Sv per year)
External exposure from the cloud	2.19E-05	3.86E-06	2.58E-05	(man Sv per year)
External irradiation from deposited activity	2.08E-03	3.66E-04	2.44E-03	(man Sv per year)
Ingestion of agricultural products:				
Beef	1.38E-07	2.44E-08	1.63E-07	(man Sv per year)
Sheep	1.07E-06	1.89E-07	1.26E-06	(man Sv per year)
Cereals	8.82E-05	1.56E-05	1.04E-04	(man Sv per year)
Green vegetables	6.06E-07	1.07E-07	7.13E-07	(man Sv per year)
Root vegetables	2.65E-07	4.67E-08	3.12E-07	(man Sv per year)
Milk	1.69E-08	2.99E-09	1.99E-08	(man Sv per year)
Sub-total	9.03E-05	1.59E-05	1.06E-04	(man Sv per year)
Ingestion: special cases:				
H - 3	1.39E-07	2.46E-08	1.64E-07	(man Sv per year)
C - 14	2.67E-01	4.70E-02	3.14E-01	(man Sv per year)
Total	**2.73E-01**	**4.82E-02**	**3.21E-01**	(man Sv per year)
Occurence of health effects in local (public) population:				
Fatal cancer	1.36E-02	2.41E-03	1.61E-02	(cases per year)
Non-fatal cancer	3.28E-02	5.78E-03	3.85E-02	(cases per year)
Severe hereditary effect	2.73E-03	4.82E-04	3.21E-03	(cases per year)

The expected human health effect at the global scale, resulting from emission of H–3, C–14 and Kr–85, are calculated in the Global Health Effects Worksheet (Table 5).

The final stage of the impact pathway analysis is to value the health endpoints in money terms. Estimates of the economic unit value of radiological health effects, made as part of the ExternE project, are provided in Table 6 below.

The Value of a Life Year Lost (VLYL) approach is used to assess the value of fatal cancers. The latter differs from the former in that it takes into account the latency period of different types of cancers. A component related to the cost of illness has also been included. The values given in Table 6 are based on a discount rate of 0 percent.

Table 5. Global Health Impacts of Atmospheric Releases

Total collective dose:			
	H - 3	8.24E-03	(man Sv per year)
	C - 14	1.07E+01	(man Sv per year)
	Kr - 85	4.07E-05	(man Sv per year)
Total		**1.18E+01**	**(man Sv per year)**
Occurence of health effects in global (public) population:			
	Fatal cancer	**5.92E-01**	**(cases per year)**
	Non-fatal cancer	**1.42E+00**	**(cases per year)**
	Severe hereditary effect	**1.18E-01**	**(cases per year)**

The economic unit values shown in Table 6 are specific to the European Union, however, and an adjustment is needed prior to their application in Indonesia. This adjustment is to reflect differences in income and hence, willingness-to-pay regarding the valuation of the health damages.

Table 6. Economic Unit Value of Radiological Health Effects
(0% discount rate)

Approach	Fatal Cancers (US $[1995] per case)	Non-fatal Cancers (US $[1995] per case)	Sever Hereditary Effects (US $[1995] per case)
VLYL	2,855,800	589,500	4,113,400

Source: Markandya (1997)

The required adjustment is simply; if a damage cost estimate is available from European Union (EU) and we want to convert it into a damage cost estimate for Indonesia (Ind), we may use the following formula (Markandya, 1998):

$$Damage_{Ind} = Damage_{EU} \cdot (PPP\ GNP_{Ind} / PPP\ GNP_{EU})^{E} \qquad \ldots (1)$$

where PPP GNP is the purchasing power parity Gross National Product and *E* is the elasticity of damages with respect to PPP GNP (which is assumed to be equal to 1).

Once the appropriate adjustments have been made to the unit values listed in Table 6, the estimated damages (in terms of adverse health effects) resulting from one year of atmospheric releases from a nuclear facility are calculated according to equation:

$$D_h\,(l,r,g;\,\text{VLYL}) = N_h\,(l,r,g) \times V_h\,(\text{VLYL}) \qquad \dots (2)$$

where

$D_h\,(l,r,g;\,\text{VLYL})$ = The total damage in terms of health effect h on the 'local', 'regional' and 'global' scale, valued using the VLYL approach (US $\$^{1995}$ per year of release).

$N_h\,(l,r,g)$ = The total occurrence of heath effect h on the 'local', 'regional' and 'global' scale (number of cases per one year of releases).

V_h (VLYL) = The adjusted economic unit value of health effect h based on the VLYL approach (US $\$^{1995}$ per case).

Table 7 and Table 8 show the estimated total damage cost for each health effect, at the local, regional and global scale; a total table is also provided. These values represent the endpoint in the impact pathway analysis of routine atmospheric releases from nuclear facilities.

Table 7 shows that global impact cost has highest value of health effects. Based on the monetary damage, fatal cancer is the main health impact of routine atmospheric releases. The valuation of health effect is carried out by a Value of Life Year Lost (VLYL) approach. Table 8 shows that the total impact of atmospheric releases is about US$ 5.60E-05 per-kWh.

Table 7. Impacts of Routine Atmospheric Releases (Monetary value of health effects)
(US $1995 per year of releases)

No.	Health Effects	Local	Regional	Global	Total
1	Fatal cancer (VLYL approach)	4628.25	816.75	200810.45	206255.45
2	Non-fatal cancer	2292.89	404.63	99484.08	102181.60
3	Severe hereditary effect	1333.27	235.28	57848.15	59416.71

6.2. Result of Nuclear Water Impact Assessment

The calculation of water impact is based on the Impact Pathways Assessment, starting from the calculation of radionuclide concentration in the coastal water, commited effective dose, and the impact to the calculation of monetary valuation. In this study, we consider the coastal, therefore liquid effluents are discharged to the sea, so there are no freshwater fish impacts. The pollutants that assessed are Iodine, Cobalt and Cesium.

Based on the radionuclide concentration in fish, the Committed Effective Dose (CED) of these pollutants to the population surrounding within a radius 100 km is calculated.

Table 8. Total Impacts of Routine Atmospheric Releases (Monetary Damages)

No.	Total Impact of Routine Atmospheric Releases	US$/year	US $/kwh
1	Total Impact using VLYL approach	3.68E+05	5.60E-05

Impact of radionuclide pullutants to the people, which is represented by the number of fatal and non-fatal cancer and hereditary effect incidents, is calculated by considering the coefficient risk factors.

To calculated the monetary value of nuclear water impact, the transfer of unit cost of the European Union to Indonesia is considered. Furthermore, this transfer unit is used to calculated Monetary Value of the incident, after taking into account the European monetary values for radiologically induced health impact. The result of monetary valuation of nuclear water impact is presented in Table 9 below.

Table 9. Nuclear Water Impacts

Impact	Incident	Euro Mon. Value (US $/incident)	Indonesia Monetary Value (US $)
		VLYL	VLYL
Cancer (fatal)	6.55E-05	2.90E+06	2.26E+01
Cancer (non fatal)	1.57E-04	6.00E+05	1.12E+01
Hereditary effect	1.31E-05	4.10E+06	6.38E+00
TOTAL			4.02E+01
Nuclear water impact in monetary damages (Routine) VLYL : 6.11E-09 $/kwh			

6.3. Result of Nuclear Waste Assessment

In this assessment, it used data from the near surface disposal site at Aube, France. The inventory of waste disposal represents the total stored activity resulting from about 10,000 Twhe. The global impact from nuclear waste disposal were evaluated using European unit values, so the unit costs should be world estimate. Therefore, the data should considere the factor: (PPPGDPworld/PPPGDPeurope)= (6300/20269) = 0.31 (PPPDGP data from the World Development Indicators, World Bank, 2000). So, assumption of public health damage costs resulting from near disposal site is around US$ 2.54E-06 per-kWh (see Table 10).

Table 10. Public Health Damage Costs Resulting from Releases of Radionuclides from the Near-surface Disposal Site at Aube.

	Number of Fatal Cancers (US $1995 mn)	Number of Non-fatal Cancers (US $1995 mn)	Number of Severe Hereditary Effects (US $1995 mn)
Local	3.00E-02	1.00E-02	1.00E-02
Regional & Global	5.31E+01	1.82E+01	1.06E+01
Sub-total	5.31E+01	1.82E+01	1.06E+01
Total (Fatal+Non-fatal+Hereditary effect)		(million $/year)	8.18E+01
Total (Fatal+Non-fatal+Hereditary effect) using European unit (US $/kwh)			8.18E-06
Total (Fatal+Non-fatal+Hereditary effect) using World estimate (US $/kwh)			2.54E-06

Source: Markandya and Boyd, Estimating the external costs of radioactive waste disposal, IAEA, 1999.
Note:The inventory represents the total stored activity resulting from about 10,000 Twhe (=1.0E+13 kwh)
1 Twh = 1.0E+12 wh.

6.4. Result of Nuclear Accident Assessment

The calculation of total accident cost is based on the economic module of COSYMA with additional consideration on indirect cost. There are five main considerations that are taken into account, such as food ban cost, evacuation and relocation cost, indirect cost, fatal effect cost and non-fatal effect cost. All costs are expressed in Million Euro, which is then conversed into Million US$. The total (local+regional) cost of nuclear accident is around Euro 1206.4 Million or around US$ 965.1 Million). Detail result of those calculation is presented in Table 11.

Table 11. Total Cost of Nuclear Accident (1000 Mwe)

Cost Category	Local Costs	Regional Costs	Total Costs	
	Mn. Euro	Mn. Euro	Mn. Euro	Mn. US $
Food Ban	39.3	691.1	730.4	584.3
Evacuation and Relocation	11.6	0.0	11.6	9.3
Indirect Costs	63.3	0.0	63.3	50.6
Fatal Effects	169.5	166.8	336.3	269.1
Non-fatal Effects	32.6633	32.07871	64.74201	51.79361
Total	316.4	890.0	1206.4	965.1

Note: 1 US$ 1995 = 1.25 Euro 1995.

The external cost, including risk aversion is obtained by multiplying with the total cost of accident by probability of accident occurance. The external cost of nuclear accident in this assessment is around US$ 2.69E-06/kWh (see Table 12 below).

Table 12. External Cost of the Nuclear Accident

MN. EUROS	Expected Total Cost (MN. EURO)	External Cost of Accident (EUROs /kwh)	External Cost of Accident Including Risk Aversion Euros/KWh	External Cost of Accident Including Risk Aversion US$/KWh
1206.4	0.0023	3.49E-07	3.36E-06	2.69E-06

6.5. Total External Cost of Nuclear Power Plant

Total external cost of nuclear plant consider to valuing the human health effects of routine atmospheric releases from nuclear power plant and the nuclear accidents. External cost from routine atmospheric emissions using VLYL approach is expressed in US$ 5.60E-05 per-kWh (this value is more than 91% of the overall externality cost). (please see Figure 3).

Meanwhile, external cost from nuclear accident, nuclear water impact and radioactive waste disposal (using VLYL approach) are expressed in US$ 2.69E-06 per-kWh, US$ 6.11E-09 per-kWh and US$ 2.54E-06 per-kWh respectively.

Calculation result of total externality cost using a Value of Life Year Lost (VLYL) approach is around US$6.12E-05 per-kWh.

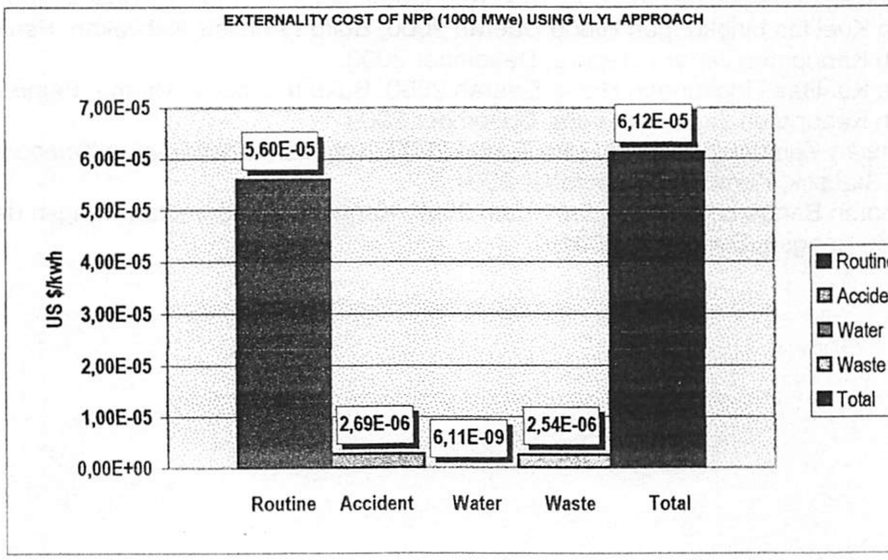


Figure 3. External Cost of NPP (1000 Mwe) Using VLYL Approach

6. CONCLUSIONS

1. The valuation of health effect in the externality study is carried out by a Value of Life Year Lost (VLYL) approach. The impact of routine atmospheric releases by using the VLYL approach is about US$ 5.60E-05 per-kWh. Routine emissions impact is dominated in overall externality cost. Meanwhile, external cost from nuclear accident,

nuclear water impact and radioactive waste disposal (using VLYL approach) are expressed in US$ 2.69E-06 per-kWh, US$ 6.11E-09 per-kWh and US$ 2.54E-06 per-kWh respectively.

2. Total externality cost (total damage cost) of NPP (1000 Mwe) using a VLYL approach is around US$ 6.12E-05 per-kWh.

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