ECONOMIC COSTS OF ENVIRONMENTAL DEGRADATION OF AIR AND WATER IN EGYPT

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ABSTRACT

Cost of Environmental Degradation (COED) is considered one of the main environmental performance indicators that provides degradation values per environmental category. The results of the COED could help inform decision-maker choices and improve the sustainable and growth strategies' outcomes. This paper sets out to produce a rapid COED for Egypt for the year 2020 for air and water as the two main environmental categories that impact the quality of life of Egyptians. As the first COED estimates for Egypt date back to the early 2000s, and partial COEDs were carried out in the 2010s, this paper would update the results for the most recent years for which data are available as means of determining the trends in environmental degradation and the specific areas of air and water where sustainable environmental management is most needed. Also, the results of the COED provide Egyptian policymakers with an important tool to support them in making informed choices and better integrate the environment into economic development decisions.

Keywords: Cost of environmental degradation, ambient air pollution, indoor air pollution, monetary valuation of environmental impacts, damage costs of environmental impacts

INTRODUCTION

This paper attempts to derive environmental damage costs for Egypt. It is essentially based on a process initiated under the former World Bank Mediterranean Environmental Technical Assistance Program (METAP). The results could be used as an instrument for integrating environmental issues into economic and social development planning. While there are a number of challenges encountered in assigning monetary values to environmental degradation, such estimates can be nonetheless a powerful tool to raise awareness about environmental issues and facilitate progress toward sustainable development.

The rapid COED will assess the damage costs resulting from environmental impacts that can be understood as a measure of the lost welfare due to environmental degradation. Such a loss in welfare includes (but is not limited to):

- Loss of healthy life and well-being of the population (e.g., premature deaths, pain and suffering from illness, absence of a clean environment);
- Economic losses (e.g., reduced soil productivity, lower production values, lower land/real estate values); and
- Loss of environmental opportunities (e.g., reduced recreational value of lakes, forests, eco-tourism etc.).

SCOPE

This study will provide a first order of estimates of the COED in Egypt in 2020 for the following environmental categories: air and water with specific focus on: (a) air (outdoor and indoor); (b) water quality (lack of access to water quality/quantity and sanitation, and level of hand washing with soap), water resource quality. Also, each of the environmental categories will be divided into two economic categories: (a) impact on health and quality of life; and (b) impact on natural resources.

PROCESS

The process of estimating the COED involves placing a monetary value on the consequences of such degradation. This often implies a three-step process:

i. Quantification of environmental degradation (e.g., monitoring of ambient and indoor air quality, river/lake/sea water quality).
ii. Quantification of the consequences of degradation (e.g., negative impacts on health from air pollution, impact on water body quality).
iii. A monetary valuation of the consequences (e.g., estimating the cost of ill health).

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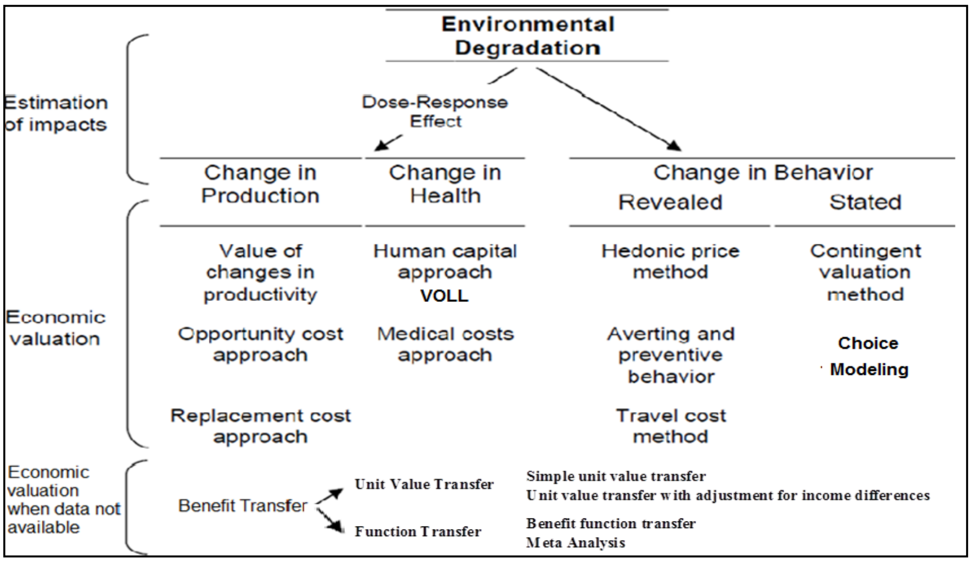
The main methods for estimating the impacts are grouped around the three pillars with specific techniques under each pillar as illustrated in Figure 1.

Figure 1: Estimation of Impacts and Associated Economic Valuation Techniques



Source: Adapted from Bolt et al. (2005)

METHODOLOGY

The methodology and the sources of data used to estimate the COED for air and water degradation in this paper are presented in the following:

Ambient Air Pollution

- Risk factors from PMx and Ozone are used to derive Disability-Adjusted Life Year (DALY) lost are from the Institute for Health Metrics and Evaluation (IHME) <www.healthdata.org> for year 2019 and used for 2020. Population exposed is the Urban population. Although the rest of the population is exposed to a lesser extent to air pollution, it is not considered in the analysis.
- Monetization used is the Value of Statistical Life (VSL) as derived from OECD (2015) and adjusted to 2020 prices is used for premature death using (Navrud, 2009) benefit transfer method, whereas the human

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capital approach is used for morbidity as follows: the GDP/capita/year in 2020 is used per DALY lost (Murray and Lopez, 1996) which is a health metric equivalent to 1 lost year of healthy life.

- Navrud (2009) for the benefit transfer method.

Several epidemiological studies revealed even stronger correlations recently between long-term exposure to $PM_{2.5}$ and premature mortality (e.g., Apte et al., 2015; Brauer et al., 2016; Gakikou et al., 2017; Leliveld, 2019; etc.). In this case, the Stanaway et al., 2017 dose-response functions are used by IHME and were considered for Egypt.

For the Valuation, the VSL is used as mentioned above whereas the World Bank and IHME, 2016 used the Human Capital Approach based on the forgone labor output, which is calculated as the present value of expected lifetime labor earnings. The estimation considers: the forgone income of people aged 15-64, estimated for each 5-year cohort; the labor force participation rate; the expected annual income growth rate (3 percent per year; and the discount rate (the net present value of the forgone income is discounted at 4 percent.

The benefit transfer involves transposing existing monetary environmental values estimated at one site (study site) to another (policy site), usually with similar context or physical characteristics (Navrud, 2009). There are two approaches for the benefit transfer: the unit value transfer; and the transfer function. In this case, we will rely on the unit value transfer and more specifically on the transfer of the unit to adjust for differences in income value as described in Navrud (2009).

The transfer of the unit to adjust for differences in income value is as follows:

$$WPp = WPs \times (Yp / Ys)^{ß}$$

Where:

WPp = willingness to pay by household in policy country

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WPs = willingness to pay by household in study country

Yp = income in the country policy denominated in purchasing power parity dollar (PPP$)

Ys = income in the country of study denominated in purchasing power parity dollar (PPP$)

ß = income elasticity for different environmental goods and services, which are considered normal goods, are typically greater than 0 (perfectly inelastic which would have meant that the WPp = WPs only adjusted by income where ß = 1.2).

In this case, the income elasticity is assumed to be conservatively set at 1.2 (more inelastic), which means that the percentage responsiveness of quantity demanded (in this case the resource) is significantly and slightly lower than the percentage change in income. Incidentally, a new study, which provides VSL through a benefit transfer method estimates to monetize fatality risks in 189 countries.

Thus, the VSL for Egypt is estimated at US$ 278,993 whereas the DALY lost is equivalent to the GDP per capita and amounts to 3,548 in 2020. The results for Ambient Air Pollution (AAP) including $PM_{2.5}$ and Ozone, Indoor Air Pollution (IAP) and Water, Sanitation and Hygiene (WASH) are illustrated in Table 1.

Table 1: Burden and Valuation of AAP, IAP and WASH

	Unit	Per 100,000 Pop			Pop Exposed	Pop Affected	VSL	GDP	Total
		Mid	Low	Hi	#	#	US$	US$	US$
AAP PM									11,542,750,110
Mortality	#	91.41	67.45	117.97	43,781,728	40,021	278,993		11,165,526,551
Morbidity	DALY lost	242.85	173.62	316.46	43,781,728	106,324		3,548	377,223,559
IAP									13,249,093
Mortality	#	0.07	0.02	0.17	60,829,320	45	278,993		12,558,486
Morbidity	DALY lost	0.32	0.13	0.66	60,829,320	195		3,548	690,607
AAP Ozone									199,100,845
Mortality	#	1.63	0.69	2.77	43,781,728	714	278,993		199,100,845
Morbidity	DALY lost	-	-	-	43,781,728	-		3,548	-
WASH									2,043,329,328
Diarrhea									
Mortality	#	5.88	3.38	9.01	102,334,403	6,017	278,993		1,678,771,499
Morbidity	DALY lost	100.41	61.09	149.18	102,334,403	102,754		3,548	364,557,829
Thyphoid and ParaThyphoid									
Mortality	#	0.29	0.12	0.55	58,552,675	170	278,993		47,373,704

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Morbidity	DALY lost	0.28	0.15	0.47	58,552,675	164		3,548	581,665
Schistosomiasis									72,630,760
Mortality	#	0.24	0.15	0.36	58,552,675	141	278,993		39,205,824
Morbidity	DALY lost	16.09	8.56	27.99	58,552,675	9,421		3,548	33,424,936

Source: IHME website <www.healthdata.org>; and Author

Indoor Air Pollution

- Risk factors to derive DALY lost are from IHME website <wwwhealthdata.org> for year 2019 and used for 2020. Population exposed is the population living in slums and rural areas.
- Monetization used is the Value of Statistical life as derived from OECD (2015) and adjusted to 2020 prices are used for premature death using Navrud (2009) benefit transfer method whereas the human capital approach is used for morbidity as follows: the GDP/capita/year in 2020 is used per DALY lost.

Water

- Unimproved Water, Sanitation and Hygiene
  - Risk factors to derive DALY lost are from IHME <www.healthdata.org> for year 2019 and used for 2020. Population exposed is the entire population (see Table 1).
  - Monetization used is the Value of Statistical life as derived from OECD (2015) and adjusted to 2020 prices is used for premature death using (Navrud. 2009) benefit transfer method (using adjusting for purchasing power for parity and elasticity for preference) whereas the human capital approach is used for morbidity as follows: the GDP/capita/year in 2020 is used per DALY lost.
  - GDP figures are derived from World Bank WDI (2021).
- Water Resource Quality
  - Arif and Doumani (2013).
  - Baker et al. (2007).
  - Navrud (2009) for the benefit transfer method.

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- GDP figures are derived from World Bank WDI (2021).

- Water Resource Quantity
  - Arif and Doumani (2013).
  - Doumani (2019).

For water resource quality, a benefit transfer was used based on a contingent valuation carried out in the United Kingdom to improve the water quality of all bodies as illustrated in Figure 2. Hence, Baker et al. (2007) results of £ 299 per household per year over 8 years to improve water body quality was used and adjusted to 2020 prices due to the difficulty of accounting for the multiplicity of water pollution sources in Egypt. An elasticity of 1.2 was also used for the benefit transfer.

For water resource quantity, the unaccounted-for-water (31% across Egypt) for the water used for domestic and industrial use was considered as a proxy for accounting for the water that was extracted which affected environmental flow, ecosystem services, rising water table salinity and decreasing water table level. The tariff per household was considered (US$ 0.80, 7.0 and 14.6 per 15, 50 and 100 m3 per month respectively). The same unaccounted-for-water could be done for irrigation but was not considered as unaccounted- for irrigation figures are not readily available. Incidentally, the mismanagement (that is, water resources are available but are not efficiently provided to the consumer) cannot account for environmental degradation per se as they are the result of poor service delivery. However, alternative water services from wells and trucks could result in water contamination which is partially captured under WASH above although additional diseases such as hepatitis, helminth, blue baby syndrome, etc. could also follow.

Figure 2: Use and Non-Use Value of Water Resource Improvements

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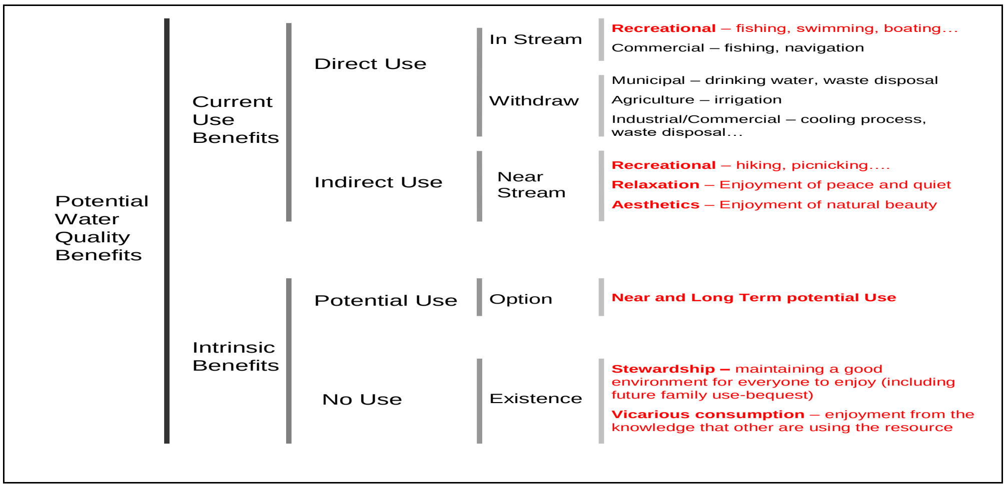

Source: Baker et al. (2007).

RESULTS AND DISCUSSION

The results of the air and water degradation in Egypt as estimated by using the rapid $COED_{2020}$ aforementioned methodology are presented in Table 2 both in terms of absolute costs and relative costs as percentage of GDP. Figure 3 presents the relative costs of degradation as percentage of GDP for air and water in 2020 compared to those estimated for 1999.

The rapid $COED_{2020}$ in Egypt for air and water degradation ranges between 2.9% and 5.4% of GDP in 2020 with a mean estimate of 4.2% equivalent to about US$ 15.29 billion in 2020 as compared to a mean estimate of 3.1% of GDP in 1999 equivalent to around US$ 2.82 billion. The mean estimate for degradation to air in 2020 amounts to 3.3% of GDP which is equivalent to about US$ 12.14 billion increasing from 2.1% of GDP (about US$ 1.91 billion) in 1999. However, while the mean estimate for the degradation of water has decreased from 1% of GDP in 1999 to 0.87% of GDP in 2020, the magnitude of degradation has by far increased in absolute value from US$ 0.91 billion in 1999 to US$ 3.15 billion in 2020.

Ambient air pollution (method: exposure-based approach with annual average is decreasing and is about 60 micron/m^3 where only the urban population of 43.8 million is considered). The cost of degradation amounts

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to US$ 11.92 billion equivalent to 3.2% of GDP in 2020 and is attributable to point and non-point pollution in terms of motorized vehicles, boats and planes, industries, household emissions, communal/individual power generator emissions, occasional solid waste and tire burning, dust (mining and construction), etc. The main sub-categories include health (mortality and morbidity although cost of illness is not considered per se but the forgone economic value-added is considered as a proxy) whereas the agricultural production yield reduction and infrastructure decay due to air pollution were not quantified although there is a growing body of work emphasizing this evidence.

Indoor air pollution (method: risk factor approach). The health effects of indoor air pollution afflict the poor and the most vulnerable mainly in slums and rural areas (total population exposed reached 60.8 million in 2020. The burden of indoor air pollution mean damages is significantly smaller than ambient air pollution as most household use clean cooking and heating fuels: US$ 0.01 billion, or 0.004% of GDP.

Ambient ozone pollution (method: risk factor approach). The effects of ambient ozone pollution in terms of mortality are increasing with a cost of degradation amounts to US$ 0.21 billion equivalent to 0.1% of GDP in 2020.

Water (methods: risk factor approach for health, stated preference benefit transfer, productivity loss and opportunity cost). The cost of degradation amounts to US$ 3.15 billion equivalent to 0.9% of GDP in 2020 and is higher than the $COED_{1999}$ in absolute terms as previously mentioned. The main sub-categories include drinking water and/or sanitation and/or hygiene (WASH), water resource quality and water resource quantity. WASH is derived from the burden of traditional water-borne diseases. So far, micro-plastics is not considered among water-borne diseases because their worldwide deleterious effects still need to be backed by scientific evidence. Still, micro-plastics are also contaminating water

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bodies' food chain (water, salt, fish, crustaceans, mollusks, etc.) and are detected in the human body. Conversely, water bodies' contamination by chemicals and heavy metals is also prevalent in Egypt and affects water, the food chain and ecosystem services although their health impact (chemicals and heavy metal accumulation including lead in human bodies above accepted thresholds are dangerous and toxic leading to organ damage, immune system weakening, reproductive problems and birth defects, effects on the children mental cognitive or physical development, and cancer) are, despite the existence of international dose-response functions, more difficult to quantify in the absence of comprehensive data on chemical and heavy metal accumulation in human bodies. Water resource quality in terms of surface, ground and marine water is based on a benefit transfer of a contingent valuation carried out in the United Kingdom due to the multiplicity of the sources of pollution (Wazne and Korfali, 2016) such as agricultural runoff, waste leachate, oil spills, vessel sewage and waste illegal discharge, etc.). Water resource quantity degradation is associated with the unaccounted-for-water that is lost in the domestic distribution network and the opportunity cost of planting wheat and rice is used as a proxy for the irrigation water losses that reach some 3 billion m^3 per year.

Table 2: Annual Rapid Cost of Environmental Degradation - Mean estimate, 2020

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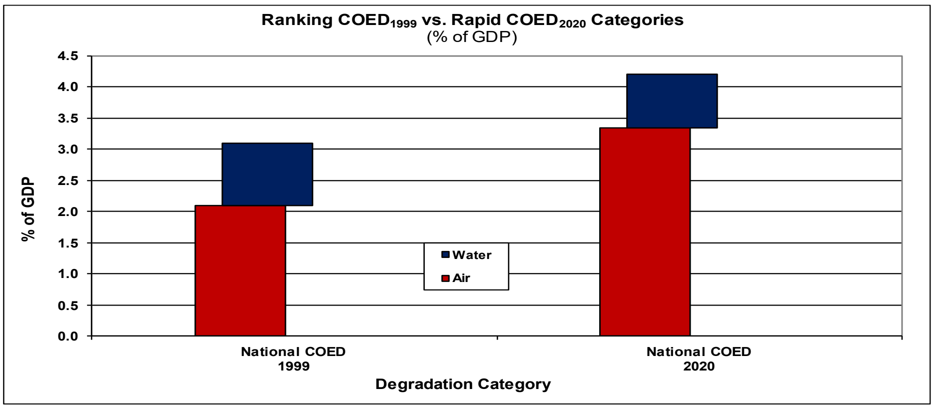
Category	Population	COED2020			
	Exposed	Lower Bound	Upper Bound	Middle Bound	
	million	US$ billion	US$ billion	US$ billion	% of GDP
Air		**8.68**	**15.61**	**12.14**	**3.3%**
-Ambient Air	*43.8*	*8.59*	*15.24*	11.92	3.2%
-Indoor Air	*60.8*	*0.00*	*0.03*	0.02	0.0%
-Ambient Ozone	*43.8*	*0.08*	*0.34*	0.20	0.1%
Water		**2.17**	**4.13**	**3.15**	**0.9%**
-Drinking Water, Sanitation and Hygiene	*102.3*	*1.21*	*3.20*	2.21	0.6%
-Water Resource Quality	*102.3*	*0.50*	-	*0.25*	0.1%
-Water Resource Quantity	*102.3*	*0.46*	*0.92*	*0.69*	0.2%
Total		**10.85**	**19.74**	**15.29**	**4.2%**
GDP_{2020}				365.25	
Egypt Population 2020	102.3				

Source: Estimated by using the aforementioned methodology

Figure 3: $COED_{1999}$ vs. Rapid $COED_{2020}$ - Mean estimate



Source: World Bank (2002) and Table 2

CONCLUSIONS AND RECOMMENDATIONS

The differences between the results of the $COED_{1999}$ and $COED_{2020}$ could be attributed essentially to the marginal degradation of the environment over the period. That is, the rapid $COED_{2020}$ for air and water increased in both relative (except for water) and absolute terms (for both air and water) when compared to the $COED_{1999}$. The main reasons for such an increase in absolute terms are as follows: (i) substantial negative impacts to health from mainly ambient air pollution and to a lesser extent indoor air pollution; and (ii) water-borne diseases associated with poor water and

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sanitation provision as well as behavior practices for a small segment of the population, whereas water quantity degradation exceeds water quality.

Overall, environmental health risk exposure levels in Egypt are a concern, and aggregate health effects and their costs are substantial (Larsen 2019). This was substantiated by the COED estimated for air and water degradation in this paper.

With regard to air quality, Egypt, with the support of international development partners, has made tremendous efforts over the past several years to reduce pollutant emissions, especially in Cairo and major cities, by improving the monitoring (both ambient air and end of stack) of criteria pollutants namely PMx and lead that are the most harmful compounds to human health. Furthermore, there are ongoing efforts in Egypt to implement policies in the four main sectors contributing the most to air quality degradation; that is, industry, transportation, energy and waste. These policies include several actions such as: better enforcement, introduction of market-based incentives, setting-up an intermediation mechanism for heavy polluters, and an ambitious relocation of polluting industries to other governorates. Moreover, while Egypt needs to continue its efforts in controlling and preventing outdoor PM pollution, it should focus more on $PM_{2.5}$ given the gravity of the health impacts these fine particulates have.

As regards the water sector, Egypt has initiated a mega program for rural sanitation since the mid-2010s. However, improvements should be continued in the water and sanitation sector, with emphasis on ensuring good quality drinking water, environmentally safe sanitation, and continuing efforts to improve hand washing and other hygiene practices.

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التكاليف الاقتصادية للتدهور البيئي للهواء والماء في مصر

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المستخلص:

تعتبر تكلفة التدهور البيئي (COED) أحد مؤشرات الأداء البيئي الرئيسية التي توفر قيم تدهور لكل فئة بيئية. بحيث يمكن أن تساعد نتائج هذه التكلفة التقديرية COED في تقديم خيارات لصانع القرار مبنية علي معلومات وتحليلات كمية وتحسين نتائج استراتيجيات النمو والاستدامة. تهدف هذه الورقة إلى تقدير تكلفة التدهور البيئي بشكل مبسط COED لمصر لعام ٢٠٢٠ للهواء والماء باعتبارهما الفئتين البيئيتين الرئيسيتين اللتين تؤثران على جودة حياة المصريين. نظرا لأن تقديرات COED الأولى لمصر تعود إلى أوائل العقد الأول من القرن الحالي ، وتم تنفيذ COEDs الجزئية في عام ٢٠١٠ ، فإن هذه الورقة ستحدث نتائج السنوات الأخيرة التي تتوفر عنها البيانات كوسيلة لتحديد الاتجاهات في التدهور البيئي و المناطق المحددة للهواء والماء حيث تشتد الحاجة إلى إدارة بيئية مستدامة. كما توفر نتائج COED لواضعي السياسات البيئية في مصر أداة مهمة لدعمهم في اتخاذ خيارات مستنيرة ودمج البيئة بشكل أفضل في قرارات التنمية الاقتصادية.

الكلمات المفتاحية: تكلفة التدهور البيئي ، تلوث الهواء المحيط ، تلوث الهواء الداخلي ، التقييم النقدي للتأثيرات البيئية ، تكاليف الأضرار الناجمة عن التأثيرات البيئية