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METHODOLOGY OF SOCIAL AND ENVIRONMENTAL EXTERNAL COSTS ESTIMATION IN THE UKRAINE'S ENERGY SECTOR

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Paper objective is analysis of the external costs assessment model for the eco-social damage, and/or human capital losses caused by environmental pollution from the energy enterprises in Ukraine. Using the given method, necessary initial socio-economic parameters were defined and used for calculating the social costs of capital health losses in Ukraine due to deterioration of the environment, and due to the negative impact of energy sector on the air quality for the period 2002-2013. On the proposed technique determines the range value of social losses due to the negative impact of energy on air quality in Ukraine excluding future external costs for years 2002 – 2013 ranges from 1.6 – 4.5% of GDP, and the range of values of taking into account future costs is 2.0 – 6.2% of GDP.

***Keywords*:** *environmental pollution, energy, external costs, assessment, human capital losses.*

Introduction. Internalization of external costs into the full energy production cost is considered as a potentially efficient policy instrument with regard to energy for reducing its negative impacts and move towards a more sustainable energy supply and use. Consideration of externalities is useful for providing an indication of damages/benefits associated with different energy options, for assessing trade-offs between different energy options, for ranking energy options and it can serve as a basis for the introduction of economic instruments to reflect the eco-social costs of energy. During the recent years in Ukraine the problem of the external cost's assessment caused by enterprises' activity eco-destructive impact has been of great attention due to increase of market influence on the

economy management and attempts of the governmental agencies to operate with more appropriate indicators of the damage caused by violation of the environmental regulations, and emergencies. In addition, one of the conditions of Ukraine's integration into the European Energy Community is the implementation of the Directive 2001/80/EC on the thermal power generation companies' emission reduction to improve the Ukrainian citizens' health, but without losing the reliability of the integrated energy system.

Analysis of recent researches and publications. A foreign and domestic literature review reveals various approaches to the estimation of environmental external cost as a tool to internalization these costs into the full energy production and consumption. In these publications the basic thematic areas of author's research are:

– introduction to Environmental Externality Costs (Koomey J., Krause F. [1]);

– Market Failure and Energy Policy (Fisher A. C., Rothkopf M. H. [2]);

– the current attempts to internalize external costs from energy production, distribution and use with special consideration for the role of the ExternE project in influencing environmental policy in the United Kingdom and the European Union (Fouquet R, Slade R, Karakoussis V, Gross R, Bauen A, Anderson D.) [3];

– Economic Costs Of Air Pollution-Related Health Impacts, an Impact Assessment Project of Austria, France and Switzerland (Seethaler R., Künzli N., Sommer H. et al.) [4];

– the evaluation or external costs of Power Production in South Eastern Europe (Butti G., Papaemmanouil A., Andersson G.) [5];

– ExternE-Externalities of Energy Methodology (Bickel P., Friedrich R., et al.) [6];

– using the analysis with Global Multi-regional MARKAL Model as tool of Internalisation of external cost in the power generation sector in Switzerland [7];

– an overview of methodology to measure the health, environmental and infrastructure external costs and benefits associated with the production and consumption of energy in the United States (U.S. Congress, Atomic Energy Agency) [8, 9];

– the using the SimPact Computer Code and Willingness to Pay survey, calculated the external costs of the morbidity and mortality of population due to the air pollutants emitted from an electricity enterprises in Ukraine (Matsuki Y., Bidyuk P., Kalnytskyi G., Brondzia O., et al.) [10, 11].

Previously unsettled problem constituent. The above trips to the evaluation are labor-intensive and require a modernized system of emissions monitoring from the activities of energy enterprises.

Main purpose of the article is to develop an external cost estimation caused by environmental pollution from the industrial enterprises in Ukraine with using health capital losses' evaluation.

Results and discussions. ***Overview of the international practices***. As stated in International Atomic Energy Agency technical reports [9] it was Olav Hohmeyer and Richard L. Ottinger [12] who popularized the notion that externalities and social costs result from electrical power production and emphasized putting the impacts into monetary terms. These studies have been widely criticized for an unnecessarily naive and incorrect analysis of nuclear accidents and an inconsistent comparison with air pollution. However, they laid additional groundwork for, and inspired, the major studies that took place in the early 1990s.

As Hodas [13] describes, in 2005 the United States Congress commissioned a study from the National Academy of Sciences that would "define and evaluate the health, environmental, security, and infrastructure external costs and benefits associated with the production and consumption of energy that are not or may not be fully incorporated into the market price of such energy, or into the Federal revenue measures related to that production or consumption" (§1352 Energy Policy Act of

2005 (PL109-58)).

Funding for the study was not provided until 2008 (Consolidated Appropriations Act of 2008 (PL 110-161)). The National Academy of Sciences report Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use [14] was the first comprehensive study since Ottinger's [12] "the most prominent study in the United States ... that quantified the environmental costs of electric power generation". As stated in the report "Ottinger et al followed a five-step procedure in using these studies to value environmental damages: emissions, dispersion, exposure, impacts, and damages".

A variety of monetization techniques can be used to assign monetary values to environmental effects (damages and benefits) of electricity production. The US Office of Technology Assessment [15] has published a background paper which provides a good discussion of monetization techniques.

The damage based valuation approach uses the Willingness to Pay (WTP) concept, which is central to modern economic theory. According to the International Atomic Energy Agency technical reports [9], this approach was used by most of the seven states in the USA that recently required regulated electrical utilities to consider quantitative externality values in their integrated resource planning. These regulations were established before the spate of studies done in Europe and North America established the damage function approach as being feasible and practical, thus eliminating the need for control cost estimates as measures of environmental damages (though estimates of control costs are still important for comparing the benefits of pollution abatement or prevention relative to the associated costs).

In according to [6] also Bickel and Friedrich (2005) used ExternE method for the evaluation of the external costs. The core element of this method is the so called "Impact Pathway Approach" (IPA), which consists of a "bottom-up" analysis: profits and costs are evaluated by following the path of the pollutant from the emission sources through the qualitative changes of air, soil and water to the physical effects on receptors, before this is expressed in monetary terms. Furthermore, with the ExternE method, both the emissions directly originating from energy transformation, and the ones derived from processes such as fuel preparation, construction of power stations and waste management are taken into consideration. Therefore, it concerns a "Life-Cycle Analysis" (LCA).

***External cost estimation caused by environmental pollution from the industrial enterprises in Ukraine with using health capital losses' evaluation*.**

In this approach, the economic value is based on the medical costs of the health condition plus the lost productivity caused by the illness or injury. The medical costs are the in-patient costs, out-patient costs, medical prescription costs and long term care costs.

The lost productivity is measured in terms of the earnings that would be equivalent to the lost time from work. Based on the analysis made by Afanasiev A. A. [16], Revich B. A. [17], Korchagin V. P. [18], Shmakov D. I. [19], Karaieva [20, 21] the following Table 1 structures the content of the basic methods for the health capital losses' evaluation.

At present, two main areas for the human health capital economic losses' research have been formed.

The first area is based on the concept of the disease burden cost, where its' direct and indirect costs are economically estimated. The direct cost takes into account the cost of treatment, care and rehabilitation of patients, other costs fall on the public health protection measures and also on social transfers (disability pension, social security payments). The indirect costs are the lost profits resulting from labor time losses.

Table 1. **The basic methods for the health capital losses' evaluation** (developed by authors)

Method	The matter
Evaluation of human capital	Evaluation of lost earnings as a result of illness or premature death due to pollution; valuation of one year of life, determined as a ratio from dividing the average annual salary by the coefficient that characterizes the share of wages at the created benefits value; assessment of the tax revenues loss due to lower profits resulted from the loss of working time.
Differentiation of wages	Assessment of the differences in wages in the areas with different levels of pollution
Contingent valuation	Establishing the price people are willing to pay to avoid pollution based on surveys.
Avoiding expenses	Evaluation of the cost on disposal activities or reducing the impact of pollution
Costs of disease.	Estimation of lost working days taking into account medical and related additional costs due to pollution.

The second is based on the human life value concept and is based on the valuation of the human life itself, excluding the cost of healthcare and the social transfers and the losses related to the shortfalls products. This value, for example according to [19], can be calculated by the formula:

$$P_{Lt} = S_t (L_t - A),$$

where P_{Lt} – the cost of lost years as a result of death of a person at the age A in the year t; S_t – the value of a statistical life in the year t; L_t – the life expectancy in the year t; A – the age of the deceased person.

Value P_{Lt} characterizes the economic cost to society resulting from the premature death of a person who did not reach the average life expectancy. Methodological approaches to assessing the value of statistical life are divided into two groups:

1) the human capital evaluation methods;

2) the willingness to pay evaluation methods (contingent valuation).

Sociological and statistical studies show that people' assessment of their life' costs often corresponds to the size of annual earnings multiple of the size of the average life expectancy. Valuation of the lost years of life has humanitarian nature, as it is designed to reflect the value of every life.

However, in the majority of the above approaches valuation of the human health capital loss is made excluding the time factor and reducing the value of costs and revenues to one time point, or the value of annual losses is forecasted based on the hypothesis of a zero growth rate. It should be noted that the methodological basis for determining the people health capital loss due to eco-destructive impact of energy sector are the above observed approaches.

The calculation method. The basis of the method used is the accounting the current and future periods' social costs on the following several organizational and economic levels [20, 21]:

– at the macroeconomic level as the sum of three values – the medical care budgetary costs, temporary working disability payment and compensation to the families due to the breadwinner's loss from the social insurance funds, and the costs (turnout shortage or lost profit in GDP) of production for the period of illness and premature death of the younger and the working age people;

– at the household level (or from the actually patient's own point of view);

– losses from the morbidity rate increases – consist of additional costs for drugs, paid medical services and others.

The recent researches in environmental

epidemiology and health risk analysis, particularly Revich [17], have shown that the magnitude of environmental factors influence, which determines deteriorating health equity, can reach in some cases up to 30-60%. According to the World Health Organization (WHO) 20% of economic losses from increased morbidity, disability and mortality are due to poor environmental quality. The corresponding assessments, given by Revich [17], indicate that about 7% of mortality among the urban population (approximately 16 thousand death cases for the 15 million people) living in the most polluted areas is due to the influence of polluted air. Thus, states that the loss in the year t is equal to:

$$U_{es} = C_e (L_t + D_t + M_t), \quad (1)$$

where L_t – the total loss from the population morbidity in the year t; D_t – total loss due to disability in the year *t*; M_t – economic losses resulting from premature mortality of younger and working age population in the year *t*; C_e – environmental factor that corresponds to the share of the health capital losses due to the environmental pollution.

According to the WHO data and research results presented by Revich [17] formula (1) can be specified the following way:

$$U_{es} = 0,2(L_t + D_t) + 0,07 M_t. \quad (2)$$

Ukraine's energy generating sector is one of the major air pollutants. The energy sector produces about 40% of total pollutants emitted to the atmosphere. Taking into account the impact of the sector on the level of air pollution, energy ratio (C_{en}) is equal to 0,4 and formula (2) can be specified as follows [20, 21]:

$$U_{es} = (0,2(L_t + D_t) + 0,07 M_t)0,4 \quad (3)$$

Let us consider the calculation matter of each structural formula (3) component.

Loss due to disease per year is associated with the loss of benefits in GDP, the treatment costs and social insurance payment. Therefore, the annual economic losses $L_{t,}$ caused by diseases with temporary loss of working ability, should be determined by the following formula:

$$L_t = n_{adt} (GDP_t + P_t + L'_{dt}), \quad (4)$$

where GDP_t – *GDP* per worker in the economy in the year *t*; P_t – payment for a sick leave certificate in case of adult and child population's illness during the year *t*; L'_{dt} – the cost of treating a patient during the year *t*; n_{adt} – the number of people, conventionally absent from work during the year *t;* $n_{yt} = Nt / 365$, *Nt* – the absolute number of temporary disability days' in the year *t*.

Diseases of the unemployed in the economy population lead to lower economic losses as they are related only to the treatment costs. However, in cases of child population diseases there are also GDP losses and aid payments from social insurance funds due to forced working disability of parents caused by caring for a sick child. Therefore, to assess adequately the economic losses caused by disease of the younger and working age the GDP losses' calculation and sick leave payments for the period of parents' disability are required.

To assess correctly the economic losses caused by the general level of diseases, it is necessary to consider the costs due to different types of diseases at different ages, as there are diseases "more expensive" and "less expensive", and the size of the treatment costs depends on age. In general, formulas of losses caused by diseases considering the treatment costs by the age and by the type of diseases can be written as follows:

$$L_{jt} = \sum_j \left(N_{jit} \cdot L'_{hjit}\right) j = 1, 2, \ldots, n; j = const$$

$$\sum_j \left(N_{jit} \cdot L_{hjit}\right) i = 1, 2, \ldots, m; i = const, \quad (6)$$

where N_{jit} is j-disease ilnesses (number of cases) at the age of *i* in the year *t*; L'_{hjit} – the average amount of *j*-disease healing losses for the age *i* in the year *t*.

Formula (5) takes into account the economic costs depending on the age while formula (6) – depending on the disease.

Loss caused by disability is characterized also by lost profit in GDP production of current and future periods, the cost of treating persons with disabilities and pensions paid. Different groups of disability are referred to patients, depending on the degree of working ability. Patients who received I and II disability groups are disabled or their working ability is limited. Macro-economic losses (MEL) due to complete working disability of group of persons under 16 years can be calculated by the formula:

$$I_{nAt} = n_{At}\,[(L_{dt} + P_{Dt})\,(L_t - A') + (GDP_t \cdot S)], \quad (7)$$

where L_{nAt} – losses resulting from total working disability of n – number of people recognized as disabled at the age of A' in year t ($A' < 16$); n_{At} – the number of fully recognized people as disabled by the age A' in the year t; L_{dt} – the cost of disabled treating during the year t; P_{Dt} – annual disability pension in the year t; L_t – life expectancy in the year t; A' – the age of full recognition of working disability (disability); S – average seniority, that is 40 years.

In case of total working disability of working age people, formula (7) takes the form:

$$L_{nA't} = n_{A't}\,[(L_{dt} + P_{Dt})\,(L_t - A') + GDP_t(A_r - A')], \quad (8)$$

where A_r is the retirement age.

To determine the total losses caused by disability, the values of losses for all age groups are added:

$$L_t = \Sigma L_{nAt}\,. \quad (9)$$

However, according to this approach the value of economic costs' as a result of disability is taken at the level of the year for which the calculation of losses is made, excluding increase (reduction) of future expenses resulting from economic growth or recession. Therefore, for correct economic costs' assessment the future economic costs discounting procedure should be applied according to the rule of compound interest. In practice, a special coefficient, which is defined by the compound interest formula, is used:

$$E_t = (1+r)^{-(t-1)}, \quad (10)$$

where E^t – is the discount coefficient; r – discount rate.

In our opinion, the discount factors of direct and indirect costs can be calculated by using the annuity factor (annuity is an annual payment). Discount coefficient of lost benefits in GDP production of the next period (E_{GDP}) according to the economic context is equivalent to compound interest function – an increased annuity amount. The increased annuity amount can be calculated by the simplified formula:

$$E_{GDP} = (1+ E)^T - 1/E, \quad (11)$$

where E is the compound interest rate used for calculation, T – period of discounting the economic losses, years. According to the formula (7), T is equal to the average seniority – $T = S$ and according to the formula (8) – the difference between the planned year of retirement and the recognition age of full working disability – $T = (R - A')$.

The value of the loss can be made based on the hypothesis of a constant rate of growth of the GDP per capita by 3% per year which is acceptable in terms of sustainable economic development. It should be noted that in reality the value of loss may be positive during economic growth and negative during the recession. The discounting rate of direct costs due to the treatment of disabled persons and pensions' payment in the year t can be calculated by determining the present value of annuity by the simplified formula:

$$E_{cost} = 1 - (1+ E)^{-T}/E, \quad (12)$$

where T is the period equal to the difference between life expectancy and the recognition

age of full working disability (disability) – $T=(L_t - A')$, according to the formulas (7) and (8).

Considering the mentioned above formulas (7) and (8) can be written as follows:

$$I_{nA't} = \sum_{t=t_b}^{T} n_{A't}[(L_{dt} + P_{Dt})(1 - (1+E)^{-T}/E) + GDP_t((1+E)^T - 1/E)], \quad (13)$$

where t_b is time base for summarizing the costs variable in time.

Loss due to premature mortality is associated with the lost profits in GDP and social benefits to families due to the loss of breadwinner. Losses due to mortality under the age of working age without considering time factor are defined by formula:

$$M_{nAt} = n_{At} GDP_t S, \quad (14)$$

where M_{nAt} is the loss due to n-number people's death at the age of t ($A<16$ years).

Considering the time factor formula (14) takes the form:

$$M_{nA,t} = \sum_{t=t_b}^{T} n_{At}[GDP_t((1+E)^T - 1/E)], \quad (15)$$

where T is equal to the average seniority.

According to the formula (15) the losses from mortality of working age people can be defined, but T will be equal to the difference between the planned year of retirement age A_p and the age of the deceased A, – $T = (A_p - A)$. If the deceased were families' breadwinners, the compensation to the families due to the loss of breadwinner is also considered:

$$M_{nA,t} = \sum_{t=t_b}^{T} n_{At}[(C_t + GDP_t)((1+E)^T - 1)/E)], \quad (16)$$

where C_t is the annual amount of compensation to the family due to the loss of breadwinner.

Loss due to mortality in all age categories during the year t (M_t) is calculated as the sum of the values of losses due to mortality in each age category:

$$M_t = \Sigma M_{nAt}.$$

Calculation of the social losses of health capital due to eco-destructive energy impact (particularly on the state of the air) for the period 2002-2013. Based on the official statistics data (State Statistics Service of Ukraine) input socio-economic and environmental indicators, necessary for calculating the target type of losses, are presented in Table 2.

Table 2. **Dynamics of the indicators necessary for calculating the losses due to the energy sector eco-destructive impact** (developed by authors)

Indicator	Year							
	2002	**2003**	**2004**	**2005**	**2007**	**2009**	**2011**	**2013**
GDP in actual prices, M UAH.	225810	267344	345113	441452	720731	913345	1302079	1 408 889
The number of employed population at the age of 15-70, thousand people.	29156	29315	29515	29656	29800	29586	29090	28842
GDP per one employed in the economy of working age, UAH	7745	9120	11693	14886	24186	30870	44760	48849
Average nominal monthly salary, UAH	376	462	590	806	1351	1906	2633	3026
The energy sector share of pollutants' emission into the atmosphere in the total emissions from stationary sources, %	58,8	59,0	56,7	58,3	54,8	57,8	52,57	53,29

Using the given above method for the target losses determination, appropriate calculations were carried out. The results of macro-economic assessment of losses (MEL) in Ukraine due to deterioration of the environment, and due to the negative impact of the energy sector on the air quality (MEL^e) are shown in Table 3.

Table 3. **The dynamic of the losses due to deterioration of the environment and due to the negative impact of energy sector on the air quality in Ukraine's for the period of 2002-2013,** (developed by authors)

Components of the losses	Years							
	2002	**2003**	**2004**	**2005**	**2007**	**2009**	**2011**	**2013**
Due to disability								
MEL excluding future costs, M UAH	81510	93360	123970	124770	153350	203880	155540	153240
MEL^e, M UAH	6521	7468	9918	9982	12268	16310	14443	15259
% from GDP	2,88	2,79	2,87	2,26	2,25	2,28	1,11	1,08
MEL considering the future costs, M UAH	117140	145620	191730	192780	220500	285740	267400	265100
MEL^e, M UAH	9371	11649	15338	15422	17640	22859	21992	22080
% from GDP	4,15	4,36	4,44	3,49	3,24	3,21	1,69	1,57
Due to the population's mortality								
MEL excluding future costs, M UAH	30759	45871	47518	67723	78638	108533	50204	31164
MEL^e, M UAH	2460	3669	3801	5417	6291	8682	6016	6493
% from GDP	1,09	1,37	1,10	1,20	1,16	1,22	0,46	0,46
MEL considering the future costs, M UAH	49142	50062	74524	97168	113210	156753	84395	78692
Components of the losses	**Years**							
	2002	**2003**	**2004**	**2005**	**2007**	**2009**	**2011**	**2013**
MEL^e, M UAH	3931	4004	5961	7773	9056	12540	5351	5895
% from GDP	1,74	1,50	1,73	1,76	1,66	1,76	0,41	0,42
Due to population's diseases								
MEL excluding future costs, M UAH	1212	1739	2107	2592	3219	4199	4768	4471
MEL^e, M UAH	33,94	48,69	58,99	72,57	90,13	117,6	133,5	125,2
% from GDP	0,015	0,018	0,017	0,016	0,017	0,016	0,01	0,01
Total amount of losses								
MEL considering the future costs, M UAH	167490	197420	268360	292530	336930	446690	351795	343792
% from GDP	74,2	73,8	77,8	66,27	61,92	62,65	27,01	24,40
MEL excluding future costs, million hr.	112269	139231	171488	192493	231988	312413	210512	188875
% from GDP	49.72	52.08	49.69	43.60	42.63	43.82	16,17	13,41
MEL^e considering the future costs, M UAH	13302	15653	21299	23195	26696	35399	27343	27975
% from GDP	5,89	5,86	6,17	5,24	3,70	3,88	2,10	1,99
MEL^e excluding future costs, million hr.	10193	11186	13778	15472	18649	25110	20593	21877
% from GDP	4,51	4,18	4,00	3,51	2,59	2,75	1,58	1,55

Results, presented in Table 3, show that during 2002-2013 years the MEL^e magnitude excluding future costs ranges between 1,6 – 4,5% of GDP, while the MEL^e magnitude considering the future costs ranges between 2,0 – 6,2% of GDP.

Conclusions and further researches directions. The results of macro-economic assessment of losses due to the negative impact of energy on the air quality were obtained to display the diapason and dynamics of the value of Ukraine's total health capital losses' due to disability, mortality and diseases during 2002-2013. It is grounded that the given total value of health capital losses' caused by eco-destructive impact of the energy enterprises can serve as an effective indicator of the sustainable development policy effectiveness.

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МЕТОДОЛОГІЯ ОЦІНКИ ВАРТОСТІ СОЦІАЛЬНИХ І ЕКОЛОГІЧНИХ ЕКСТЕРНАЛІЇВ ЕНЕРГЕТИЧНОГО СЕКТОРУ УКРАЇНИ

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Стаття присвячена аналізу концептуально-методичних основ оцінки соціальних і екологічних екстерналіїв (зовнішніх втрат) в результаті діяльності підприємств енергетики. Доведено актуальність використання методики оцінки економічних втрат капіталу здоров'я людини для визначення негативних екстернальних ефектів внаслідок екодеструктивного впливу енергетики. На основі запропонованої методики визначено, що діапазон величини соціальних втрат внаслідок негативного впливу енергетики на якість атмосферного повітря в Україні без урахування майбутніх витрат за 2002-2013 рр. коливається в межах 1,6 – 4,5% до ВВП, а діапазон даної величини з урахуванням майбутніх витрат становить 2,0 – 6,2% до ВВП.

Ключові слова: *забруднення навколишнього середовища, енергетика, зовнішні витрати, екстерналії, оцінка втрат капіталу здоров'я людини.*

МЕТОДОЛОГИЯ ОЦЕНКИ СТОИМОСТИ СОЦИАЛЬНЫХ И ЭКОЛОГИЧЕСКИХ ЭКСТЕРНАЛИЕВ ЭНЕРГЕТИЧЕСКОГО СЕКТОРА УКРАИНЫ

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Статья посвящена анализу концептуально-методических основ оценки социальных и экологических экстерналий (внешних потерь) в результате деятельности предприятий энергетики. Доказана актуальность использования методики оценки экономических потерь капитала здоровья человека для определения негативных экстернальных эффектов в результате экодеструктивного влияния энергетики. На основе предложенной методики определено, что диапазон величины социальных потерь вследствие негативного влияния энергетики на качество атмосферного воздуха в Украине без учета будущих расходов за 2002-2013 гг. колеблется в пределах 1,6 – 4,5% к ВВП, а диапазон данной величины с учетом потерь будущих периодов составляет 2,0 – 6,2% к ВВП.

Ключевые слова*: загрязнение окружающей среды, энергетика, внешние издержки, экстерналии, оценка потерь капитала здоровья человека.*