ENERGY AS AN INDICATOR OF HUMAN DEVELOPMENT: A STATISTICAL APPROACH

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Introduction

The concept of "economic development" has become synonymous with "growth in per capita income" since the Second World War.[1] The conventional practices of measuring level of development have employed the use of per capita gross domestic product (GDP). However, the quality of life depends not only on income, but also on a variety of physical and social arrangements[2] and the relationship between per capita GDP and the indicators of these arrangements is controversial.[3] For this, the criticism on the application of national income, which can be traced back to 1954, has led the dissatisfied experts to search for a composite measure of development.[4]

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Claiming that measuring human development only by GDP per capita obscures the fact that the primary objective of development is to benefit people, *Human Development Report 1990*[5] proposed the Human Development Index (HDI). The HDI is aimed at measuring the average achievements of a country in basic dimensions of human development in addition to economic indicators. Although 19 other indices of development have been proposed since 1990,[6] none attracted the attentions as the HDI did by the development economists, policy makers, and by public.[7] At present, it is generally accepted that the HDI is the most comprehensive index measuring the human development besides all criticism since its proposal.[8]

However, the problems related with sustainability of development remains to be solved. As well noted by Anand and Sen (p. 2030),[9] *"We cannot abuse and plunder our common stock of natural assets and resources leaving the future generations unable to enjoy the opportunities we take for granted today."* Although some important steps have been taken in the 1987 World Commission on Environment and Development and later in the 1992 United Nations Conference on Environment and Development,[10] there have not been many calls for improvement of the HDI by taking environmental aspects into account, which is called "greening of the HDI".[11]

Energy is essential for greening of the HDI because it is central to economic, social, and environmental dimensions of sustainable development.[12] World Energy Council[13] reports that one of the most important components of sustainable development is to achieve accessibility, availability, and acceptability in energy. Although the worldwide energy sales consists only about 3% of the world's gross domestic product, economic growth is not sustainable because some amount of energy and materials are used to produce goods and services.[14]

The investigation of the relationship between energy and social life goes back to *Energy and Power* published in 1971. In this special volume of Scientific American, in addition to the recognition of the fact that *"Man's expanding need for energy creates difficult economic, social, and environmental problems"* by Starr (p. 37),[15] the flow of energy in hunting, agricultural, and industrial societies have been studied thoroughly by Kemp, Rappaport, and Cook, respectively.[16] Later, Lasso de la Vega and Urrutia, and Johansson and Goldemberg proposed environment-sensitive human development indices such as the Environment Endangerment Index (EEI), Pollution-Sensitive Human Development Index (HDPI), and Human Disruption Index (HDI).[17] Some institutions such as NEF (The New Economics Foundation), WUPPERTAL (Wuppertal Institute for Climate, Environment, and

Energy), and SERI (Sustainable Europe Research Institute) also developed various forms of Sustainable Human Development Indices (SHDI).[18]

However, only a few literatures are available on the relationship between the HDI and energy. Suárez[19] appears to be the first to study this relationship by using the HDI data for 1992 and energy data for 1991. Several authors have later used his calculations concluding that energy has a determinant influence on the HDI, particularly in the early stages of development.[20]

In this study, we aimed at integrating an energy component to the HDI. To achieve this goal, we first recalculated the weights of the HDI to form the MHDI (Modified Human Development Index). This is done by applying the PCA (Principal Component Analyses) to the life expectancy, education, and GDP data of 173 countries given in *Human Development Report 2002 and 2003*.[21]

The next section includes the attempts to integrate an energy index into the MHDI. For this, four energy-related indicators given in *Human Development Report 2003*[22] are used: the TPEC (total primary energy consumption per capita in koe, kilogram-of-oil-equivalent in 2000), the ELEC (electricity consumption per capita in kWh in 2000), the PROD (GDP per unit of energy use in PPP US $ per koe in 2000), and ENVI (CO_2 emission per capita in metric tons in 1999). Since the data are available for 116 countries, the following processes are carried out on these countries only.

The next step is the formation of the EN index by composing the TPEC and ELEC indices. The EN index is then integrated into the MHDI to form an energy-adjusted human development index, EHDI. The correlation of the MHDI and EHDI is also done in this section. Finally, the justification of the EHDI is discussed in the last section.

Recalculating the Weights of the HDI

The latest *Human Development Report*[23] defines the HDI as *"a composite index measuring average achievement in three basic dimensions of human development- a long and healthy life, knowledge, and a decent standard of living."* The HDI is calculated as a composite index of indicators, reflecting three major dimensions of human development such as life expectancy (LIFE), education (EDU), and income (GDP). The indices of each indicator are first created by standardizing the actual values relative to a minimum value. Performance of each dimension is expressed from 0 (poorest performance) to 1 (ideal performance). The

HDI values of each country are then computed by adding one-thirds of the three dimension indices.

However, although the HDI methodology has remained the same since 1990, weighing the three dimensions equally has been criticized frequently.[24] UNDP[25] also admits, *"In the ideal world, the 'meta production function' of human development would be specified, and the contribution of each variable to human development would be its weight."* As properly stated by Noorbakhsh,[26] determining the weights of each components *a priori* implies the existence of a universally acceptable human development function, which he believes not the case. Therefore, derivation of the weights by using multivariate techniques such as principal component analyses will present the best option for weight selection as noted by Srinivasan, and Booysen.[27] This method will also eliminate the problems discussed by several authors.[28]

The application of multivariate methods to the HDI weighing is first attempted by the junior author of this paper, who tried to investigate the correlation among variables by carrying out a principle component analysis on the 1992 data.[29] Later, having discussed his results, UNDP[30] concluded, "*...the PCA confirms the equal weights but also points to the high degree of correlation."* Noorbakhsh[31] also used a similar methodology for the 1995 data for the same purpose.

The correlation matrix and the PCA results of the 2000 data for 173 countries are given in Tables 1 and 2, respectively. The correlation coefficients between each index vary from 0.761 to 0.794 and the component loadings of the LIFE, EDU, and GDP indices are 0.925, 0.912, and 0.926, respectively.

The weights of principal indices are then added up to 1 to find the new coefficients of the following MDHI equation as follows:

$$MHDI=0.3348*LIFE+0.3301*EDU+0.3351*GDP \quad (1)$$

The new weights in the formula 1 are very similar to "one-thirds" previously recorded by several others.[32] Additionally, the correlation between HDI and MHDI rankings is found to be significant at 0.01 level as a result of Kendall's tau-b test. However, the frequency histogram in figure 1 shows that 83 countries, consisting 48% of the data, changed their ranks in degrees varying from -4 (decreasing 4 ranks) to +5 (increasing 5 ranks). The number of countries whose ranks are increased 1 is 30, consisting 17% of the data and whose ranks are decreased 1 is 26, consisting 15% of the data. The remaining 27 countries, consisting 16% of the data, changed their ranks more than or equal to 2 or less than or equal to 2.

The highest positive rank change occurs in the USA with a value of +5, indicating that this country's performance from the HDI to the MHDI is the maximum compared to the others. The other positive rank changes are +4 in Bahrain and Oman, +3 in Austria, Peru, and Sri Lanka, and +2 in Ireland, Chile, Antigua and Barbuda, Venezuela, El Salvador, and Côte d'Ivoire. On the other hand, the negative changes are -4 in Sweden, Denmark, and Maldives, -3 in Hungary and Zambia, and -2 in Korea, Poland, Kuwait, Russian Federation, Romania, Saint Lucia, Brazil, Armenia, Georgia, and Turkmenistan.

The EN Index and the EHDI

Among the energy-related indicators given for 116 countries in *Human Development Report 2003*, the TPEC and the ELEC are related to the energy consumption of the countries, whereas the ENVI is a measure of environmental degradation and the PROD is related to the energy productivity of the economic activity of countries. The PROD is the reciprocal of energy intensity, which is the ratio of primary energy consumption per unit of economic output.[33]

These indicators are first standardized by calculating the relevant indices for each country using the goalposts given in Table 3 by the following formula:

$$\textit{Dimension Index} = (\textit{Actual Value} - \textit{Minimum Value}) / (\textit{Maximum Value} - \textit{Minimum Value}) \quad (2)$$

Four indices calculated for each energy indicators by using formula 2 are then correlated with the MHDI to select the most strongly correlated ones following UNDP, Lai, and Booysen.[34] The correlation matrix given in Table 4 shows that the correlation coefficient of the MHDI with the TPEC is 0.648, with the ELEC is 0.638, with the ENVI is 0.592, and with the PROD is 0.238. The ENVI and PROD are discarded because the PCA is applied in searching linear combination only of the highly correlated indicators. Besides, the ENVI is directly related to the TPEC.

The use of the ELEC together with TPEC as energy indices appears to be quite reasonable because of the importance of electricity consumption in economies as have noted by numerous authors for more than four decades.[35] Electricity, which is not available for some 2 billion people in the world, is usually accepted as the most important energy carrier, providing an effective way to deliver energy services in modern societies.[36] The sustainable

development is considered cannot be maintained without having electricity services that are reliable, available, and affordable and, in fact, some modern services are provided only by electricity.[37] Electricity use also increases energy efficiency, making possible to achieve the large improvements in living standards without increasing energy use.[38]

The best way of compositing the TPEC and the ELEC in a combined energy index is to apply a PCA to determine the component loadings. The PCA results showed that the component loadings of the TPEC and the ELEC indices are 0.957, indicating that both indices should be summed equally to form the EN index by using the following formula:

$$EN\ Index=0.5*TPEC\ Index+0.5*ELEC\ Index \quad (3)$$

The correlation matrix given in Table 5 shows that the EN index correlates almost perfectly with the TPEC index (R^2=0.973) and with the ELEC index (R^2=0.961), whereas the correlation coefficient between the EN index and the MHDI is relatively small (R^2= 0.665). This is an expected result because the EN index is composed of the TPEC and ELEC indices while the MHDI is composed of the indices such as the LIFE, EDU, and GDP.

Since the EN index is distributed more uniformly than the TPEC and ELEC indices, the EN index, which is a composite index of both, can, therefore, be used to integrate energy indicators into the MHDI to form a new human development index called the EHDI (figure 2).

This is done by applying the UNDP (2003) methodology on 116 countries. The correlation matrix and the PCA analysis results are given in Table 6 and 7. Table 6 shows that the EN index correlates with the LIFE, EDU, and GDP indices with coefficients of 0.560, 0.500, and 0.754, respectively. Based on the component loadings given in Table 7, the formula of the EHDI is determined as follows:

$$EHDI= 0.25715*EDU+0.24399*LIFE+0.27117*GDP+0.22769*EN \quad (4)$$

The newly formed EHDI correlates with the HDI and the MHDI with correlation coefficients of 0.706 and 0.707, respectively. The closest relationship between the MHDI and EHDI is expressed by the exponential function of $y=0.1572e^{1.7806x}$ with a goodness-of-fit value of 0.9781.

Figure 3 shows the distribution of the MHDI and the EHDI between countries. The distributions are mostly parallel to each other for the medium human development countries

(the MHDI is between 0.5-0.8) but converge to each other at the ends (the MHDI is smaller than 0.5 and is bigger than 0.8). However, the best fit lines of the MHDI and the EHDI data are almost parallel to each other with formulas of $y = -0.0044x + 1.0012$ (R^2=0.9142) and $y = -0.0045 + 0.8727$ (R^2=0.906), respectively.

The significance of ranking in the HDI, MHDI, and EHDI sequences is also tested by calculating the Kendall's tau-b rank correlation coefficients. Correlation is found to be significant at 0.01 level between the HDI and the MHDI (0.987), between the HDI and the EHDI (0.921), and at between the MHDI and the EHDI (0.921). However, in spite of high correlations between the HDI, MHDI, and EHDI, considerable changes in ranks occur from the HDI and MHDI to the EHDI.

Discussion and Conclusions

The ranks and the differences between the ranks of the countries in three human development indices is given in the Appendix. The MHDI minus EHDI is given in the last column. A positive number in this column denotes the EHDI rankings are better than the MHDI rankings. A negative number means just the opposite.

The frequency histogram of the MHDI-EHDI shows that rank changes vary from -8 to +27 (figure 4). The highest frequencies occur as 31 in no change, as 14 in -1 change, and as 12 in -3 change categories. These three categories consist of about half of 116 countries. The positive rank changes occur in 27 countries whereas the negative rank changes occur in 58 countries.

Twenty-seven countries, whose rank changes from the MHDI to the EHDI are positive varying from +1 to +27, are examined in detail (Table 8). The highest positive rank changes occur in Kuwait (+27), Bahrain (+20), and United Arab Emirates (+19). Seventeen of these countries are "small consumers" according to Ediger's classification,[39] namely Kuwait, Bahrain, United Arab Emirates (U.A.E.), Turkmenistan, Trinidad & Tabago, New Zealand, Iceland, Kazakhstan, Uzbekistan, Finland, Singapore, Brunei Darussalam, Jamaica, Azerbaijan, Gabon, Estonia, and Syria. Seven "medium consumers" are Saudi Arabia, South Africa, Luxembourg, Iran, Turkey, Venezuela, and Indonesia, two "big consumers" are Ukraine and South Korea, and one "major consumer" is Russian Federation (R.F.).

These countries can be separated into two groups according to their primary energy consumption. The first group, which consists of 19 countries, can meet their energy

requirements by their fossil fuel productions. In other words, the domestic fossil fuel productions of these countries are bigger than their primary energy consumptions. As shown in Table 8, 15 of these countries are among the world's 49 biggest oil producers, 17 are among the world's 45 biggest natural gas producers, and 9 are among the world's 32 biggest coal producers. Additionally, 6 of these countries, namely Kuwait, U.A.E., Saudi Arabia, Iran, Venezuela, and Indonesia are OPEC (Organization of Petroleum Exporting Countries) members.

The remaining 8 countries consist of the second group (Luxembourg, New Zealand, Ukraine, Iceland, Finland, Singapore, Turkey, and South Korea). All of the countries in this group are the members of the OECD (Organization for Economic Cooperation for Development), which are the richest countries in the world. These countries, although depend on foreign energy sources, do not have noteworthy problems in meeting their energy requirements by imports. For instance, Singapore imports its entire energy requirement in the form of oil and natural gas. The ratio of domestic production in the form of nuclear, hydro, and fossil fuel in primary energy consumption of the remaining seven countries varies from 14.7% in South Korea to 58.4% in Ukraine.

These data indicate that the most significant factor affecting the rank changes positively from the MHDI to the EHDI is the ability of countries to meet their energy requirement. This ability is related either to the sufficiency in domestic fossil fuel reserves or to the economic well-being of the country.

We know that energy itself is not one of the basic human needs such as food, water, housing, health, education, and employment, but it is an essential ingredient of socio-economic development and economic growth.[40] Therefore, although the low energy consumption is not the main cause of poverty but the scarcity of basic human needs are and poverty and energy services exist in a synergistic relationship.[41] It is also known that availability of energy services affects the birth rates, education, mortality rates, etc.[42] For instance, around 100 million women in the world spend hours every day gathering conventional renewable energy sources only for cooking.[43]

On the contrary, a close relationship exists between efficient use of energy and living standards. It is possible to achieve large improvements in living standards without increasing energy use, but with increasing energy efficiency and the inputs of the human development is partially substitutable for one another.[44] As also clearly stated by Masera et al. (p. 2084),[45] *"…as families gain socioeconomic status, they abandon technologies that are inefficient, less costly, and more polluting."*

Therefore, the approval of the EHDI that includes indicators related to primary energy and electricity consumptions will depend on whether or not these factors are considered important in human development. Of course, in the long run, causality should run from each of the indices as noted in *Human Development Report 1993.* It will give the best answer if the energy component should be included into the human development index. It should also be noted that authors such as Neumayer[46] argues that integrating one or more variables into the HDI should not be preferred because of four major reasons. Among his reasons, two of them are applicable to our case: 1) the existence of several "modified", "reformed", "transformed" or "adjusted" HDIs[47]and 2) any change in methodology of the HDI will make comparisons through time difficult.

On the other hand, several authors agreed, *"...the HDRs seem to have become stagnant, repeating the same rhetoric without necessarily the HDI's utility".*[48] *"Additional research is certainly needed to arrive at an improved index as a measure of one of the most critical aspects of a nation's competitiveness…",*[49] and *"...a lot of work still needs to be done especially with regard to improving the database and the coverage of resources and pollutants."* [50]

At present, there is no objection to the suggestion that natural resource exploitation and environmental degradation should be taken into consideration in calculating the human development index.[51] Nevertheless, as correctly stated by Cleveland et al.[52] and Neumayer,[53] how it should be done is still a difficult question to answer.

Table 1
CORRELATION MATRIX OF PRINCIPAL VARIABLES

	LIFE	EDU	GDP
LIFE Index	1.000	0.761	0.794
EDU Index		1.000	0.763
GDP Index			1.000

Table 2
PRINCIPAL COMPONENT ANALYSIS RESULTS

Eigenvalues	2.545	0.249	0.206
Explained variance	84.835	8.305	6.861
Component loadings			
LIFE Index	0.925	-0.212	-0.315
EDU Index	0.912	0.409	0.011
GDP Index	0.926	-0.191	-0.326

Table 3
GOALPOSTS FOR CALCULATING THE ENERGY-RELATED INDICES

Indicator	Minimum value	Maximum value
TPEC	141.4	11527.8
ELEC	22	24779
PROD	1.1	11.7
ENVI	0.1	31.3

Table 4
CORRELATION MATRIX BETWEEN THE MHDI AND INDICES

	LIFE	EDU	GDP	TPEC	ELEC	PROD	ENVI	MHDI
LIFE	1.000	0.747	0.819	0.543	0.541	0.301	0.508	0.928
EDU		1.000	0.731	0.485	0.483	0.078	0.423	0.896
GDP			1.000	0.741	0.717	0.274	0.685	0.931
TPEC				1.000	0.872	-0.238	0.894	0.648
ELEC					1.000	-0.083	0.659	0.638
PROD						1.000	-0.218	0.238
ENVI							1.000	0.592
MHDI								1.000

Table 5
CORRELATION MATRIX BETWEEN THE MHDI AND THE ENERGY-RELATED INDICES

	TPEC	ELEC	EN	MHDI
TPEC	1.000	0.872	0.973	0.648
ELEC		1.000	0.961	0.637
EN			1.000	0.665
MHDI				1.000

Table 6
CORRELATION MATRIX OF PRINCIPAL VARIABLES

	LIFE	EDU	GDP	EN
LIFE	1.000	0.747	0.819	0.560
EDU		1.000	0.731	0.500
GDP			1.000	0.754
EN				1.000

Table 7
PRINCIPAL COMPONENT ANALYSIS RESULTS

Eigenvalues	3.068	0.548	0.256	0.128
Explained variance	76.689	13.706	6.409	3.196
Component loadings				
Life expectancy	0.899	-0.240	-0.326	0.166
Education	0.853	-0.382	0.355	0.026
GDP	0.948	0.084	-0.105	-0.288
EN	0.796	0.581	0.114	0.128

Table 8

FOSSIL FUEL PRODUCTION AND PRIMARY ENERGY CONSUMPTION OF 27 COUNTRIES IN 2000 IN MILLION TOE (DATA FROM BP, 2002).[54]

Countries (MHDI-EHDI is given in paranthesis)	Groups	Fossil Fuel Production				Primary Energy Consumption
		Oil	Natural Gas	Coal	Total	
Kuwait (27)	1	104.0	8.6	-	112.6	19.0
Bahrain (20)	1	-	7.9	-	7.9	γ
U.A.E. (19)	1	117.0	34.5	-	151.5	43.8
Saudi Arabia (12),	1	450.6	44.8	-	495.4	107.2
R.F. (11)	1	323.3	490.5	115.8	929.6	640.3
Turkmenistan (11)	1	7.2	39.5	-	46.7	13.6
South Africa (11)	1	-	-	126.6	126.6	108.4
Luxembourg (10) [β]	2	-	-	-	-	66.4
Trinidad & Tobago (10)	1	6.8	12.6	-	19.4	γ
New Zealand (9)	2	-	4.9	2.2	7.1	17.8
Ukraine (8),	2	-	15.0	42.2	57.2	132.6
Iran (7),	1	187.5	54.2	-	241.7	115.0
Iceland (6)	2	-	-	-	-	2.4
Kazakhstan (6)	1	35.3	9.7	38.5	83.5	40.5
Uzbekistan (6),	1	7.5	47.4	-	54.9	50.9
Finland (4)	2	-	-	-	-	26.0
Singapore (4)	2	-	-	-	-	35.0
Brunei Darussalam (4)	1	9.4	10.2	-	19.6	γ
Jamaica (4)	1	-	-	-	-	γ
Azerbaijan (4),	1	14.0	4.7	-	18.7	11.4
Gabon (3),	1	16.4	-	-	16.4	γ
Estonia (2)	1	-	-	-	-	γ
Turkey (2)	2	-	-	13.9	13.9	73.7
Syria (2),	1	27.6	3.8	-	31.4	γ
S. Korea (1)	2	-	-	1.9	1.9	191.1
Venezuela (1)	1	171.6	25.1	5.6	202.3	61.9
Indonesia (1).	1	71.5	61.7	47.4	180.6	93.8
Total		1549.7 (43%)	875.1 (40%)	394.1 (19%)	2818.9 (36%)	
World Total		3601.3	2192.2	2130.1	7923.6	

[α] Primary energy consumption comprises commercially traded fuels only.

[β] Given as Belgium & Luxembourg.

γ Not listed because not important.

Figure 1

CHANGE OF RANK HISTOGRAM. CATEGORY 1 IS +5 CHANGE, CATEGORY 6 IS NO CHANGE, AND CATEGORY 10 IS -4 CHANGE

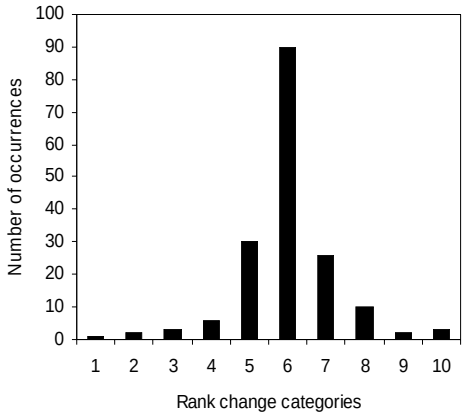


Figure 2

THE EN, TPEC, AND ELEC INDICES DISTRIBUTION BETWEEN COUNTRIES

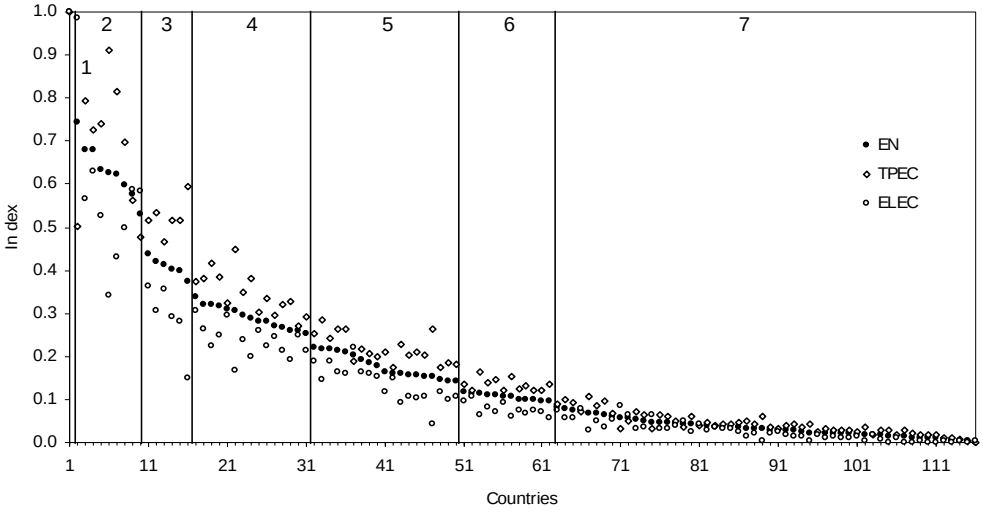


Figure 3
DISTRIBUTION OF THE MHDI AND EHDI BETWEEN COUNTRIES

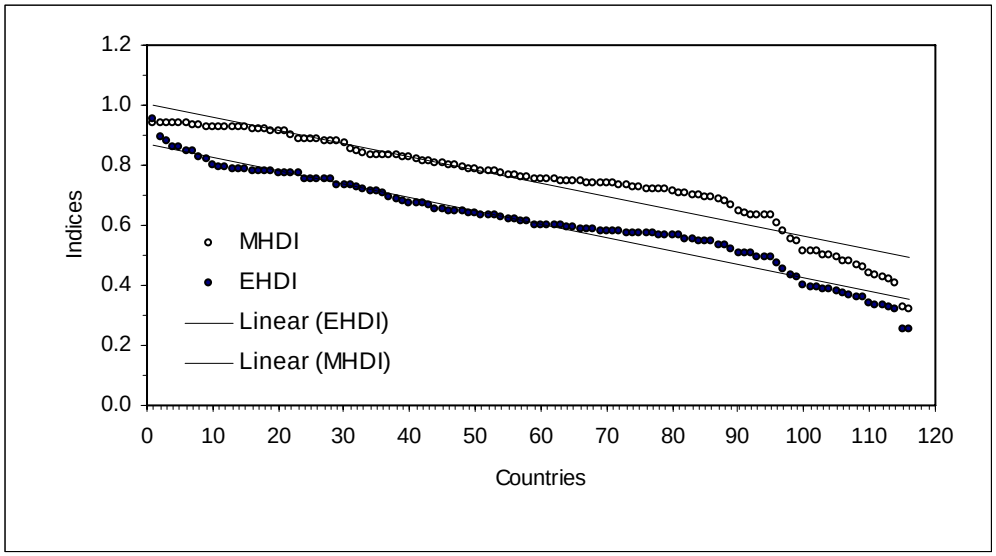
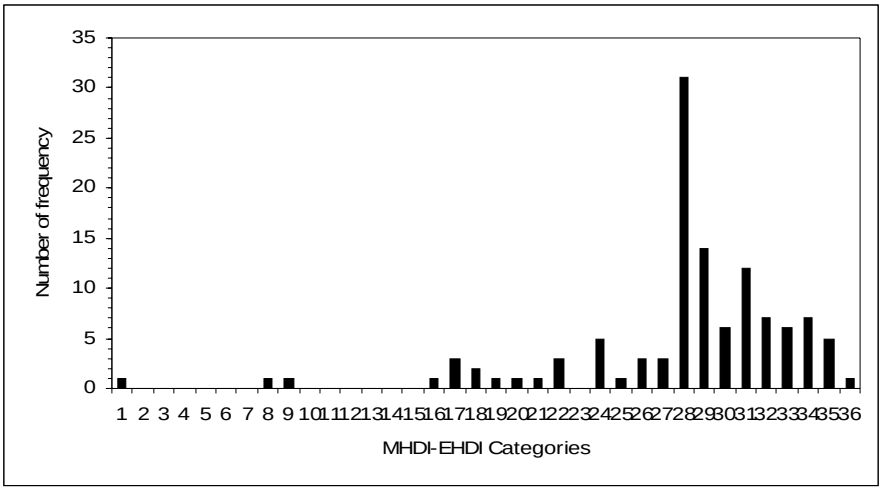


Figure 4
FREQUENCY-HISTOGRAM OF MHDI-EHDI. CATEGORY 1 IS +27, CATEGORY 28 IS 0, CATEGORY 29 IS -1, AND CATEGORY 36 IS -8.



APPENDIX. THE HUMAN, MODIFIED, AND ENERGY-ADJUSTED HUMAN DEVELOPMENT INDICES (HDI, MHDI, AND EHDI) AND THE RANK CHANGES FROM THE MHDI TO THE EHDI.

	Country	HDI	Rank	MDHI	Rank	EHDI	Rank	MHDI-EHDI
1	Norway	0.942	1	0.9398227	2	0.9509667	2	0
2	Sweden	0.941	2	0.9398154	6	0.8949271	7	-1
3	Canada	0.940	3	0.9398118	3	0.8799732	3	0
4	Belgium	0.939	4	0.9397648	4	0.8618583	9	-5
5	Australia	0.939	5	0.9397611	5	0.8585096	8	-3
6	United States	0.939	6	0.9397575	1	0.8483614	4	-3
7	Iceland	0.936	7	0.9365617	7	0.8456580	1	6
8	Netherlands	0.935	8	0.9364133	8	0.8250648	12	-4
9	Japan	0.933	9	0.9300000	9	0.8206478	11	-2
10	Finland	0.930	10	0.9297141	10	0.8001684	6	4
11	Switzerland	0.928	11	0.9266088	11	0.7955846	15	-4
12	France	0.928	12	0.9265110	13	0.7944315	13	0
13	United Kingdom	0.928	13	0.9264604	14	0.7881833	19	-5
14	Denmark	0.926	14	0.9263627	18	0.7862611	21	-3
15	Austria	0.926	15	0.9234709	12	0.7859648	18	-6
16	Luxembourg	0.925	16	0.9231705	15	0.7815515	5	10
17	Germany	0.925	17	0.9231126	17	0.7795652	17	0
18	Ireland	0.925	18	0.9230728	16	0.7791902	22	-6
19	New Zealand	0.917	19	0.9163084	19	0.7782466	10	9
20	Italy	0.913	20	0.9132067	20	0.7758816	25	-5
21	Spain	0.913	21	0.9130547	21	0.7742252	24	-3
22	Israel	0.896	22	0.8999493	22	0.7736936	26	-4
23	Hong Kong	0.888	23	0.8869454	23	0.7717317	30	-7
24	Greece	0.885	24	0.8867535	25	0.7541350	32	-7
25	Singapore	0.885	25	0.8864966	24	0.7541269	20	4
26	Cyprus	0.883	26	0.8833514	26	0.7539219	31	-5
27	South Korea	0.882	27	0.8797105	29	0.7534890	28	1
28	Portugal	0.880	28	0.8797105	27	0.7515677	33	-6
29	Slovenia	0.879	29	0.8796634	28	0.7358682	29	-1
30	Malta	0.875	30	0.8732971	30	0.7322602	34	-4
31	Brunei Darussalam	0.856	31	0.8566522	31	0.7303744	27	4
32	Czech Republic	0.849	32	0.8464531	32	0.7271996	35	-3
33	Argentina	0.844	33	0.8429569	33	0.7187023	40	-7
34	Hungary	0.835	34	0.8332573	37	0.7161671	39	-2
35	Slovakia	0.835	35	0.8329931	36	0.7122826	37	-1
36	Poland	0.833	36	0.8329569	38	0.7038740	41	-3
37	Chile	0.831	37	0.8328665	35	0.6904182	43	-8
38	Bahrain	0.831	38	0.8328013	34	0.6851783	14	20
39	Uruguay	0.831	39	0.8295476	39	0.6790978	44	-5
40	Estonia	0.826	40	0.8260659	40	0.6747557	38	2
41	Costa Rica	0.820	41	0.8197828	41	0.6737032	48	-7
42	Kuwait	0.813	42	0.8136989	43	0.6700810	16	27
43	United Arab Emirates	0.812	43	0.8103402	42	0.6680558	23	19
44	Croatia	0.809	44	0.8062939	44	0.6557457	46	-2
45	Lithuania	0.808	45	0.8060514	45	0.6537378	47	-2
46	Trinidad and Tobago	0.805	46	0.8031415	46	0.6472035	36	10
47	Latvia	0.800	47	0.7993558	47	0.6448565	50	-3
48	Mexico	0.796	48	0.7930981	48	0.6446769	52	-4
49	Belarus	0.788	49	0.7893630	49	0.6429016	49	0
50	Panama	0.787	50	0.7862830	50	0.6371621	56	-6
51	Malaysia	0.782	51	0.7798950	51	0.6343877	51	0
52	Russian Federation	0.781	52	0.7793992	53	0.6338220	42	11
53	Bulgaria	0.779	53	0.7793268	52	0.6325898	53	-1
54	Romania	0.775	54	0.7728013	54	0.6279089	55	-1

55	Colombia	0.772	55	0.7696851	56	0.6190411	62	-6
56	Venezuela	0.770	56	0.7695946	55	0.6187658	54	1
57	Thailand	0.762	57	0.7602461	58	0.6112607	59	-1
58	Saudi Arabia	0.759	58	0.7595983	57	0.6111787	45	12
59	Brazil	0.757	59	0.7529606	59	0.6022024	63	-4
60	Lebanon	0.755	60	0.7529280	60	0.6020298	61	-1
61	Armenia	0.754	61	0.7525443	62	0.6010767	67	-5
62	Philippines	0.754	62	0.7524719	61	0.6007070	68	-7
63	Kazakhstan	0.750	63	0.7493992	64	0.5988312	58	6
64	Ukraine	0.748	64	0.7492219	65	0.5960325	57	8
65	Georgia	0.748	65	0.7491495	66	0.5913784	70	-4
66	Peru	0.747	66	0.7459211	63	0.5896686	69	-6
67	Turkey	0.742	67	0.7431958	67	0.5851202	65	2
68	Jamaica	0.742	68	0.7430619	68	0.5842431	64	4
69	Turkmenistan	0.741	69	0.7394752	71	0.5828534	60	11
70	Azerbaijan	0.741	70	0.7392761	70	0.5816906	66	4
71	Sri Lanka	0.741	71	0.7391060	69	0.5795792	75	-6
72	Paraguay	0.740	72	0.7361889	72	0.5770199	73	-1
73	Albania	0.733	73	0.7326348	74	0.5746852	77	-3
74	Ecuador	0.732	74	0.7296200	73	0.5733420	76	-3
75	Dominican Republic	0.727	75	0.7263047	75	0.5725551	78	-3
76	Uzbekistan	0.727	76	0.7229316	77	0.5703256	71	6
77	China	0.726	77	0.7223851	76	0.5700982	79	-3
78	Tunisia	0.722	78	0.7199891	78	0.5698241	80	-2
79	Iran	0.721	79	0.7198444	79	0.5679273	72	7
80	Jordan	0.717	80	0.7163301	80	0.5670929	81	-1
81	Kyrgyzstan	0.712	81	0.7098335	82	0.5663246	82	0
82	El Salvador	0.706	82	0.7091893	81	0.5548872	83	-2
83	Moldova	0.701	83	0.6989902	83	0.5536735	86	-3
84	Algeria	0.697	84	0.6966848	84	0.5488226	85	-1
85	South Africa	0.695	85	0.6958270	85	0.5472321	74	11
86	Syria	0.691	86	0.6932211	86	0.5438677	84	2
87	Vietnam	0.688	87	0.6858777	87	0.5321900	88	-1
88	Indonesia	0.684	88	0.6827904	88	0.5302642	87	1
89	Tajikistan	0.667	89	0.6655700	89	0.5218254	89	0
90	Bolivia	0.653	90	0.6492508	90	0.5061691	91	-1
91	Egypt	0.642	91	0.6400796	91	0.5048491	92	-1
92	Honduras	0.638	92	0.6363301	92	0.5040865	93	-1
93	Gabon	0.637	93	0.6361057	93	0.4942427	90	3
94	Nicaragua	0.635	94	0.6332175	94	0.4922887	94	0
95	Guatemala	0.631	95	0.6300398	95	0.4918055	95	0
96	Morocco	0.602	96	0.6038183	96	0.4713974	96	0
97	India	0.577	97	0.5800290	97	0.4518041	97	0
98	Zimbabwe	0.551	98	0.5521245	98	0.4348151	98	0
99	Ghana	0.548	99	0.5496526	99	0.4265276	99	0
100	Kenya	0.513	100	0.5126746	101	0.3978406	101	0
101	Cameroon	0.512	101	0.5123163	100	0.3962555	100	0
102	Congo	0.512	102	0.5121607	102	0.3925323	102	0
103	Pakistan	0.499	103	0.4999928	104	0.3893925	104	0
104	Sudan	0.499	104	0.4970250	103	0.3893089	103	0
105	Nepal	0.490	105	0.4900253	105	0.3800601	105	0
106	Yemen	0.479	106	0.4799602	106	0.3702745	106	0
107	Bangladesh	0.478	107	0.4770214	107	0.3692505	107	0
108	Haiti	0.471	108	0.4698516	108	0.3628913	108	0
109	Nigeria	0.462	109	0.4627506	109	0.3621680	109	0
110	Tanzania	0.440	110	0.4391422	110	0.3386362	110	0
111	Zambia	0.433	111	0.4302895	112	0.3356085	112	0
112	Senegal	0.431	112	0.4287912	111	0.3349124	111	0
113	Benin	0.420	113	0.4200796	113	0.3267878	113	0
114	Angola	0.403	114	0.4035758	114	0.3185385	114	0
115	Ethiopia	0.327	115	0.3265545	115	0.2531025	115	0
116	Mozambique	0.322	116	0.3231270	116	0.2516423	116	0

Abstract

We discussed the possibility of integrating energy-related indicators into the HDI (Human Development Index). We first recalculated the weights of the HDI to form the MHDI (Modified Human Development Index) by applying the principal component analyses to the life expectancy, education, and GDP data of 173 countries given in UNDP reports. The next step is the formation of an energy index by composing the primary energy and electricity consumption indices and the integration of the EN index into the MHDI to form an energy-adjusted human development index, EHDI. In spite of high correlations between the HDI, MHDI, and EHDI, considerable changes in ranks occur from the HDI and MHDI to the EHDI. Our main result is that the most significant factor affecting the rank changes from the MHDI to the EHDI is the ability of countries to meet their energy requirement. This ability is related either to the sufficiency of domestic reserves or to the economic well-being of the country. However, the approval of the EHDI will depend on whether or not these factors are considered significant in human development.

Keywords**:** Modified human development index, Energy index, Energy-adjusted human development index

For Book Reviews: Energy, Human development, World, Human development index, Modified human development index, EN index, Energy-adjusted human development index.

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