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Human Capital & Energy the Knowledge Energy Index

*By Hemmat Safwat**

The paper introduces the measure of the ratio of the average hourly wage representing the knowledge (labor) and the average electricity price that are consumed in tasks undertaken in economies. The ratio is referred to as Knowledge Energy Index "KEI". The author introduced this term based on his previous work (the KE pair model) which stipulated that all tasks in enterprises boil down to the application of Knowledge and Energy – Safwat HH (2022). The author had expanded the model to include Capital hence the KEC model (Safwat HH (2023). KEI values were estimated using publicly available historical data for average hourly wages and electricity prices for the USA and Europe, and countries in Europe. KEI for groups of industries in the USA were estimated. Additionally, KEI tentative estimates for select developing and least developed countries are included. The trends of the calculated KEI were compared to key US economic data. A comparison is made for KEI estimates versus values from the UNDP Global Knowledge Index "GKI". KEI estimates from recent data 2024-25 for OECD, Populous nations and Select countries in Africa have been added. The newly introduced KEI can serve as a tool in economic analyses. Comments on the KEI and Human Capital highlight their role in enhancing knowledge to drive development. Commentaries also address the value of the KEI for understanding specific topics. The similarities between knowledge and energy led the author to establish a revolutionary stipulation. Knowledge can be seen as a high grade of energy" (that is a new paradigm). The KEI model could open the door for the inclusion of energy in the Economic Growth models and the Trade Theory.

Keywords *Human Capital, Knowledge, Energy, Electricity, Average Hourly Wage, Average Electricity Price, Knowledge Energy Index, Economic data for the USA and Europe.*

Introduction

At the outset, the author notes the significant contributions behind the Economic Growth Theory that led to ample understanding of Human Capital "HC" and the closely relevant Intellectual Capital "IC". The author has included several references that the reader can start with for both HC & IC (Ricardo, D. (1817), Solow, R.M. (1956), Whelan K (2021), Becker, G.S. (1964), Lucas, R.E. Jr. (1988), Kessler, A. S. & Lülfesmann, C. (2006), Spender, J.-C. (2011) and Schultz, T.W. (1961), Arrow, K. (1962), Romer, P.M. (1986), respectively. Interestingly in Romer P.M. (2025), Romer elaborated on HC his model. Leoni S, (2023) underscores education as key factor in HC. Further Table 1 contains a comparison of the main features of the principal models. One can see the topic of Economic Growth has received a lot of attention since the second half of the 20th century building on previous economic theories.

*Director, Consultant, Greece.

Table 1. *Comparison between Three Leading Models for Economic Growth Theory*

Aspect	**Solow (1956) Neoclassical Growth Model**	**Lucas (1988) Human Capital Model**	**Romer (1990) Endogenous Growth / Intellectual Capital Model**
Type of Model	Exogenous growth model	Semi-endogenous / Endogenous	Fully endogenous growth model
Main Driver of Growth	Capital accumulation and exogenous technological progress	Accumulation of human capital (skills, education)	Knowledge creation and accumulation of ideas (intellectual capital)
Role of Human Capital	Treated as part of labor input; not explicitly modeled	Central role - human capital accumulation enhances productivity	Essential human capital produces new ideas and innovations
Role of Intellectual Capital / Knowledge	Treated as an external factor (technology)	Knowledge accumulation improves efficiency of labor	Core component knowledge and innovation are endogenous, cumulative, and non- Rival
Returns to Scale	Diminishing returns to physical capital	Constant or increasing returns via human capital externalities	Increasing returns due to knowledge spillovers
Technological Change	Exogenous (outside the model)	Arises from human capital accumulation	Endogenous â€" result of intentional R&D and innovation
Policy Implications	Savings and population growth affect income levels but not long-term growth rate	Education and training policies can raise long-run growth	R&D, education, and innovation policies can sustain perpetual growth
Knowledge Spillovers	Not modeled	Implicit through human capital externalities	Explicitly modeled â€" ideas benefit the entire economy
Long-run Growth Determinant	Technological progress (external)	Human capital accumulation (internal)	Knowledge accumulation (internal)
Empirical Focus	Capital and savings	Education and learning	Innovation, R&D, intellectual property
Representative Economist(s)	Robert Solow, Trevor Swan	Robert Lucas	Paul Romer

Historically, Robert M. Solow's Neoclassical Growth Model (1956) explains long-term economic growth through the interaction of capital accumulation, labor, and technological progress. Solow argued that while increasing capital and labor inputs can raise output in the short term, diminishing returns eventually limit their impact. Long-run growth, therefore, depends on exogenous technological progress, which enhances productivity independently of capital and labor inputs. The model introduced the concept of a steady state, where capital per worker and output per worker grow at a constant rate determined by technological change and population growth. His model remains influential in explaining cross-country differences in productivity and income levels. Solow's framework established the basis for modern growth theory and inspired subsequent models—such as Lucas (1988) HC and Romer (1986) IC endogenous drivers of growth.

The author notes that the approach of the KEI as presented in this paper has evolved from a distinctively different approach that influenced by "energy" being the field he spent most of his career in. Because of his extensive experience for mor than 45 years in three leading engineering companies at different managerial levels, he had direct contact to the underlining factors that are at play in HC. He recorded his insights in his Safwat HH (2022). The book also covered the importance of innovation and R&D. Later in this paper before the conclusion section, a brief section that highlights the differences between the outlooks of representative models for HC and IC noted above with that of the KEI.

Human Capital "HC" enables developing Knowledge "K" for individuals and societies. This paper underscores the close similarity in numerous respects between Knowledge "K" and Energy "E". HC translates to K and vice versa. Through different means of HC, K grows both in quality and quantity for individuals, entities, regions and nations. When K that originally acquired by an individual is applied, the results are experienced. Similarly, E is latent in natural sources until transformed into forms that are suitable for use, subsequently when deployed, e.g. to produce heat or electricity. In this transformation losses are encountered. HC/K and E are fundamental to our lives. The K&E pair is present in each of all tasks undertaken in an enterprise, Safwat HH (2022). The source of K originates in the brains of humans. Similarly, E could be in fossil fuels in the ground (or deep sea) in the form of untapped chemical energy that when the fuel is burned is referred to as heat. When we deploy the fuel after it has been processed that we originally extract from the ground after processing in an industrial facility producing heat to melt minerals, e.g. to make steel or in a power plant to produce electricity, that is the application of E. An analogy of the generation of electricity from renewable resources can be made. Note, electricity is a form of energy, produced by the electric generator coupled to a turbine in a power plant, from wind turbines in wind farm, or from a Photo Voltaic "PV" park. We consider electricity as a premium energy because we can easily transport it and can use it for many purposes. This means electricity has a highest utility among all energy types. Hence it is considered the highest grade of energy. We also, recognize the scarcity as a major consideration for the sources of E (energy security). K has similar characteristics; it can be manifested in different types / grades. A grade is dependent on the utility level that is extracted from its application. Thus, different grades of K have their own level of availability (abundance or scarcity) do exist.

The Journey of the Author's Research behind this Paper

The author first noted parallels between macroeconomics and macro-thermodynamics in 1987 during his MBA economics course. He discussed his observations with Dr.

Ibrahim Oweiss Professor of Economics at George Town University in 1988 who saw the merits, and both agreed to investigate the similarities. They worked together for several years because the author frequently traveled for his work. This. Joint effort resulted in publishing the book Safwat HH and Oweiss IM (2002). Unfortunately, the economic community did not show enough enthusiasm for this book. Nevertheless, the authors put forth a nucleus for what was to come on the role of Technology & Energy for economic growth, Safwat HH and Oweiss IM (2005). After the author retired in 2020, he embarked on his second effort of investigations in economics. Unfortunately, the author did not have the support of Professor Oweiss this time. He concentrated initially on Business Economics, and he published the second book Safwat HH (2022). This book contains extensive information that this paper refers to as can be seen in the text of this paper. During the preparation of this book, the author put forward the notion that has been behind his search that eventually has produced this paper Safwat HH (2021), "It is all about Energy". To note that the author's publications from 2020 to 2024 were under business economics, in 2025, the author got into economics this paper and a sister paper on inflation.

With no doubt the importance of HC/K & E for the development and growth of economies have been recognized and continue to receive increased attention by economists. In line of this note, the author is introducing the KE Index "KEI" in this paper.

The author would like to note briefly the recent work of the Global Knowledge Index "GKI". Under the UNDP jointly with Muhammed Bin Rashid AlMaktoum Knowledge Foundation, published the first Global Knowledge Index for the year 2023 UNDP (2024), The second report for is available for 2024 UNDP (n.d.). The Global Knowledge Index is estimated for each country based on scores for the following factors

- Pre-University education
- Technical & Vocational Education and Training
- Higher Education
- Research, Development and Innovation
- Information and Communications Technology
- Economy
- Enabling Environment

This Global Knowledge Index "GKI" published by the UNDP is geared towards comparing how different countries stack (rank) in advancing knowledge. Another interesting country index also published by the UNDP is the Human Development Index "HDI" (n.d.)

Now we shift to E, Electricity is central to our daily life. Electricity is the preferred form of energy that countries seek to fulfill growing needs with the increased populations to support production and household demand. Electricity is generated in fossil power plants, with coal, oil, natural gas as fuels. In renewable plants wind or solar Photo Voltaic "PV", energy from wind and solar is converted to electricity. Electricity is the most valuable form of energy, compared for instance to thermal energy released when burning a fossil fuel. This is because electricity can be transported in an efficient manner through the transmission lines of the transmission and distribution subsystems of the Electrical System of a nation. Electricity has diversified applications so that is why it got to dominate many uses in Industrial, Commercial and Residential applications. A reader interested in more information about electricity and energy is referred to IEA (n.d.) and DOE (n.d.). The environmental concerns of energy generation and transport have been receiving considerable attention in recent years because of Green House Gases "GHG" primarily due to Carbon Dioxide emitted from burning fossil fuel EPA (n.d.) and World Bank (n.d.)

Paper Organization

In the first section, a brief recap of the quantitative KE pair model that was noted above (with reference to the **K* LEMS** model) is presented. In the section that follows, an outline of how the KE Index "KEI" proposed by the author is estimated from data of Average Hourly Wages "AHW" and Average Electricity Price AEP is presented. The author opted of using the word energy rather than electricity in line of what he had used in Safwat HH (2022). Noting this section which applies to an entity, a nation's economy can be seen as summation of the K&E used in the entities – mainly the private industries. Nation's KEI for the USA and Europe are presented. For the USA, the KEI historical values are covered. Examples of KEI for some private industrial groups in the USA are presented. Then the trend exhibited by the KEI versus time for the USA is compared with a few historical data of important economic parameters. A discussion of the nations' KEI estimates follows. Then a section that covers KEI for Other Countries complemented with comparisons of rankings of nations KEI and Global Knowledge Index (n.d.) GKI rankings follows. This is followed by a section that contains further insights into KEI. This is followed by a section with four commentaries "HC – Management of Technology & Technology Transfer", "KEI as tool to. identify possible countries in which to expand". The KEI relevance for promoting HC towards Growth", and "Artificial Intelligence and Knowledge & Energy (AI – K&E). This is followed by a brief under "Reflections on Current Global State". A section underlining the author's conviction that "knowledge and energy are very close" is presented. A section covering the closeness of the Trade Theory & Growth Theory and advocating inclusion of energy in the two theories.

Lastly, a Conclusions and Recommendations section is included.

The Knowledge and Energy Pair Model

Knowledge (K) and Energy (E) play key roles in the widely used "K* LEMS" system for analyzing industry growth and productivity. For reference, the reader can refer to Kotlewski, D.C. & BÅ,M. (2018), Kotlewski, D.C. (2021), Liu, G. (2017), Nikolov, P., Simons, W., Turrini, A. & Voigt, P. (2024), OMahony, M. & Timmer, M.P. (2009), Timmer, M.P., van Moergastel, T., Stuivenwold, E., Ypma, G., OMahony, M. & Kangasniemi, M. (2007), Timmer, M.P., van Moergastel, T., Stuivenwold, E., Ypma, G., OMahony, M. & Kangasniemi, M. (2007), Timmer, M.P., OMahony, M. & van Ark, B. (2007), and United Nations (2016) Chapter4.

Where (**K***), labor (**L**), energy (**E**), materials (**M**) and service (**S**) inputs. The author would argue that **K*** is primarily a product of earlier **L & E**. The Material and the intermediate entries in a Product or a Good are also result of the **L & E**. Note that the **M** that enters in a Product or a Good is a result of **L & E** that are applied to material. Finally, **S** result from L&E. In Safwat HH (2022), the author opted to avoid the word labor as it is an outmoded term as we have evolved to a dominantly service economies (in most countries) rather than in the past when manufacturing took the central stage.

With this clarification, in this paper, knowledge and energy are represented by K & E respectively. We turn to the K&E pair model. In Safwat HH (2022), the author started with introducing the qualitative version of the K&E pair model after reviewing several topics related to energy, knowledge, and the working of the human systems under the brain. Then he followed by the quantitative version of the model that is directed towards quantifying the components of the **"K* LEMS".** In the K&E model **L** is replaced by K, **E** is E.

With **K*** (K&E), **M**(K&E), **S**(K&E) thus we are to deal exclusively with K&E. One can say that **K***, **M** and **S** are functions of K&E.

How the KEI evolved

Safwat HH 2022), started with sections for Energy, Knowledge, Human Body systems working with the brain. Energy has grown to be a very large industry that supports, transport, manufacturing and electricity for residential as well as desalination, these fields are vital in our lives. Similarly, Knowledge encompasses a wide range of fields education, training, data, information, technologies, digital/computer sciences, information technology IT, computers and communications, technologies, know-how, innovations. The section of the human body and brain underlined the working of the neurons – electrical signal in the interactions of the brain with the other body systems and the storage of information. It also included a comparison of the working of a computer and the brain in handling and storing data. The discussions in these sections led the author to propose the knowledge & energy pair model Safwat HH (2022), first a qualitative model that was followed by a quantitative format. An outline of the of the quantitative model is summarized below.

The Knowledge & Energy Pair Model – Quantitative Formulation

Referring to Safwat HH (2022), for a task one would calculate: for the task sum kWh of inputs equivalent to the knowledge plus the energy's using Eq. 1.

$$\text{Sum}^{\text{task}} = x\,K_{avg,category} + y\,E_{avg.} \quad \text{kWh.} \qquad \text{Eq. 1}$$

Where x & y are the number of kWh for K and E, respectively.

The relevance of the Eq. 1 is that in the past our mind-set was aimed at optimizing energy focusing on higher 'thermal" efficiencies for electric power generation. The simple Eq. 1 and with the clear high order of magnitude of $K_{avg,category.}$ with respect to $E_{avg.}$ leads to the optimization need to include the minimization of sum of K&E. Now, as we have learned from our experiences in fossil power plants over the last 50 years, we must take into consideration the waste. One can argue that there is also waste (unwanted or less desirable result) from K entering in a task (as well as E "energy")- This the author discusses in the sister paper Safwat HH (2025). Note in general E has different ranking / categories, heat lowest and electricity highest. This amplifies the categorization (pricing) of the K and E. The author chose electricity as the base for the computation as it is the most dependable and universal commodity with the widest acceptable standard for the KEI introduced later.

Revisiting **K**(K&E), **M**(K&E) & **S**(K&E) noted earlier, we can see these under two perspectives. The first I) is under Macro-economics, as analyzed by entities producing statistics for industries in economies e.g. BEA USA (Bureau of Economic Analysis) and the European counterpart. The produced data are quite helpful in following the interrelations between different industries to evaluate **M**(K&E) & **S**(K&E). The second perspective II) is what takes place in a company as part of pricing a product (enterprises for goods in manufacturing or services), when the analyst obtains input data for the procured material/ intermediate components and services that enter in the sequence of the production. These are externally procured items. These could be referred to as external inputs. Internal accounting should include indirect costs from capital expenses and shared activities allocated to the final product. Item i) captures **K**(K&E) meaning the charges that come from the investment that the concern made to make this product. Item ii) is allocated costs from other sections/ departments in the concern that provide support (could be parts/subassembly in a manufacturing company), or specialized services.

I) Under Macro-Economics, for Industry # k
the influences of other industries from 1 to N industries

internal	a part of k - external	
K+E	Σ_{1toN} M(K,E). + Σ_{1toN} S(K,E)	Eq. 2

II) In an enterprise we deal with a sequence of processes, 1 to M, for each there

Internal $\Sigma_{p\ 1to\ M}$	External $\Sigma_{p\ 1to\ M}$ M + S	Eq. 3

Direct: K+E
Indirect: Allocated K&E capital and shared operation & maintenance

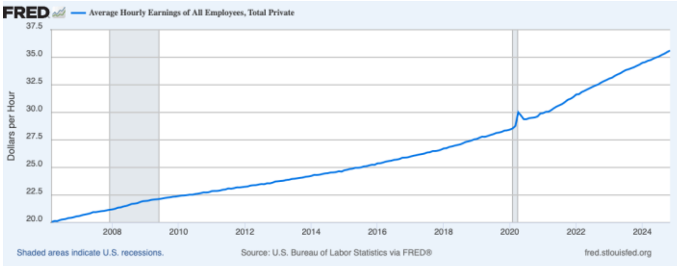
In Safwat HH (2022), the author presented examples for enterprises of estimations based on the above methodology, using pricing for electricity representing energy and labor wages for knowledge. The author underlines that the reference to the KLEMS in the context above is primarily to show how he reduced the five parameters of the KLEMS to knowledge and energy in Safwat HH (2022) and Safwat (2023).

The previous discussions are behind what led the author to introduce the KEI

Knowledge & Energy Index KEI for the USA and Europe

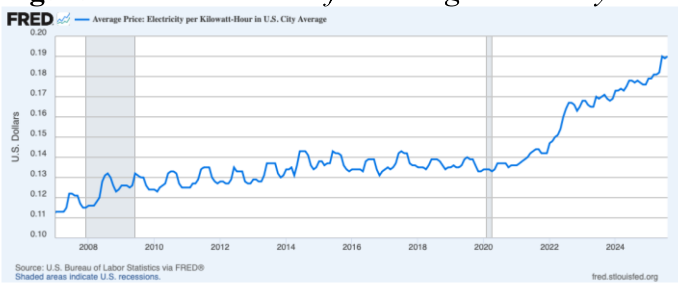
The author turned to published data for wages and electricity prices. He chose electricity rather than other energy forms.

Figure 1. *Historical Data for Average Hourly Earnings "Wage" for All Employees in the USA*



Please note that the AWG shown in Figure 1 and subsequently used in the calculations of KEI in Table 1, were only available from year 2007. **As a result, this paper analyzes the period from 2007 to 2023.** To some readers the duration of this period may appear to be short, the author feels it is sufficient to demonstration of the essence of the KEI. In the sister paper Safwat HH (2025), dealing with inflation the author analyzed the historical data between 1971 to 2024.

Figure 2. *Historical Data for Average Electricity Price $ per kWh in the USA*



Please note the larger slopes for the average wages and electricity prices from 2021 onwards. For the KEI estimates in Table 2, one should take note of the wage rate, slow increase 2008-2012, followed by almost constant steeper increase from 2012 to 2017 followed by steeper increase 2017 -2020. The rapid increase of the average wage from 2021 is noticed. On the side of the average electricity price an increase between 2008 till 2015 then an almost flat period 2015 to 2021followed with a sharp increase in 2022.

KEI Estimates for the USA and Europe over Time

Based on the data of Figures 1 & 2 the Knowledge Energy Index (KEI) Ratio were calculated and are tabulated in Table 1. Please note that KEI is the ratio $/h average hourly wage (AHW) to average electricity price (AEP) $/kWh.

Table 2. *US Averages & KEI between 2007-2023*

	Average Hourly Wage	Average Electricity Price	Knowledge Energy Index Ratio
Year	**AHW $/h**	**AEP $/kWh**	**AHW/AEP**
2007	20.91	0.12	179.37
2008	21.56	0.12	175.18
2009	22.17	0.13	174.42
2010	22.58	0.13	177.01
2011	23.03	0.13	177.66
2012	23.51	0.13	181.39
2013	23.96	0.13	181.42
2014	24.46	0.14	178.57
2015	25.01	0.14	181.22
2016	25.65	0.14	189.86
2017	26.31	0.14	191.07
2018	27.1	0.14	198.96
2019	28	0.14	205.41
2020	29.36	0.14	216.95
2021	30.61	0.14	217.52
2022	32.26	0.16	203.89
2023	33.72	0.17	200.53

In 2023 the minimum wage in the US was $ 7.25 per hour, with the average electricity price of 0.17 $/kWh, these values yield KEI of 42.

Not factoring the changes in the exchange rate between the US Dollar and the Euro "€", the electricity price in Europe is generally higher than that of the US causing the KEI in Europe to be generally lower than that in the USA, Table 3 versus Table 2 KEI.

Table 3. *KEI Estimates for Europe, 2001–2019*

Year	Average Hourly Wage €/h	Electricty Price €/kWh	KE Index Ratio AHW/AEP
2001	11.88	0.156	76.10
2002	12.55	0.162	77.60
2003	13.25	0.167	79.54
2004	14.00	0.171	81.80
2005	14.78	0.176	84.18
2006	15.62	0.181	86.47
2007	16.49	0.187	88.26
2008	17.42	0.194	89.58
2009	18.40	0.200	92.08
2010	19.44	0.205	94.72

2011	20.53	0.208	98.47
2012	21.68	0.214	101.54
2013	22.90	0.217	105.66
2014	24.19	0.220	109.81
2015	25.55	0.228	111.87
2016	26.99	0.228	118.16
2017	28.50	0.234	121.99
2018	30.11	0.241	125.12
2019	31.80	0.248	128.32

Table 4 found below contains KEI estimates for a group of European countries.

The last two columns of Table 4 show the country population and the % of the employment from the population, respectively. In 20023, Norway's KEI stands out, highest AHW accompanied by the lowest AEP (average electricity price) among the selected countries. Countries showing KEI values more than 300 are in Northern Europe and have populations less than approximately 11 million. Countries with populations more than 40 million have KEI 200 +. Electricity price influences the calculated value (Luxenberg versus Switzerland). On the lower end Soth eastern countries show KEI less than 100

Table 4. *Estimates for the Knowledge Energy Index in selected Countries in Europe – 2023*

Region/ Country	Avg. Hourly Wage AHW (€/h)	Avg. Electricity Price AEP (€/kWh)	KE Index AHW/AEP Ratio	Population	Working % of Population
Europe	31.8	0.185	172.0		
Bulgaria	9.3	0.148	62.9	6,687,717	71%
Greece	15.7	0.159	99.0	10,341,277	64%
Portugal	17	0.144	117.8	10,247,605	73%
Italy	29.8	0.190	156.8	58,973,763	62%
Spain	24.9	0.150	166.4	47,519,613	66%
Switzerkand	53.9	0.153	351.4	8,796,669	81%
France	42.2	0.231	183.0	64,754,584	69%
Germany	41.3	0.190	217.7	83,294,633	77%
Luxembourg	53.9	0.241	224.1	654,768	70%
Netherlands	43.3	0.181	239.9	17,618,299	83%
Sweden	38.9	0.098	399.0	10,612,086	78%
Belgium	47.1	0.148	318.4	11,626,140	67%
Denmark	48.1	0.132	365.5	5,910,918	78%
Norway	51.9	0.090	578.9	5,474,360	77%

KEI Estimates for Industry Groups in the USA 2023

In the previous section we addressed the history of KEI in the USA and Europe Plus how the KEI in 2023 for several countries in Europe. As noted earlier, the KEI can serve as an indicator for the performance of a company or an entity. To examine this, data a select industrial groups from the USA in 2023 were chosen to demonstrate the difference of KEI among the chosen industrial groups. The author chose the average values for the wages as was noted in the data presented for the USA, Europe and the European countries in Tables 2-4. He wanted to see the variation of the KEI within select industrial groups, see the results in Table 5.

Table 5. *Estimates of the KEI for different Industry Groups in the USA 2023*

Industry Category	Employment	Hourly Percentile 10%	Hourly Percentile 90%	Mean Hourly Wage	Knowledge Energy Index*
		$/h	$/h	$/h	MHW/AEP
00-0000 All Occupations	113,707,370			34.77	207
11-0000 Management Occupations	10,495,770	26.23	111.36	66.23	394.2
13-0000 Business and Financial Operations Occupations	10,087,830	21.86	67.55	43.55	259.2
15-0000 Computer and Mathematical Occupations	5,177,400	24.93	84.98	54.39	323.8
17-0000 Architecture and Engineering Occupations	2,539,660	24.58	76.74	47.64	283.6
19-0000 Life, Physical, and Social Science Occultations	1,389,430	21	67.44	42.24	251.4
21-0000 Community and Social Service	2,418,130	17.1	42.89	28.36	168.8
23-0000 Legal Occupations	1,240,630	22.61	81.38	64.34	383
25-0000 Educational Instruction and	8,744,560	14.74	51.02	31.92	190

Average Electricity Price 0.168 $/kWh

**KEI are calculated based on the mean wages (fifth column).*

Historical Data of Key Economic Indicators

In Figures 3 – 6, the historical data of four key economic indicators are shown for the period between 2007 to 2023.

Figure 3 is the M1 money Stock fund and Figure 4 is the effective interest rate. M1 and the Interest rate of Figures 3 and 4 are very important tools (keys to administer the monitory policy of the US) that the Federal Reserve Board (FRB) adjusts to steer the economy of the US.

Figure 3. *Chart US M1 Money Stock for the USA*

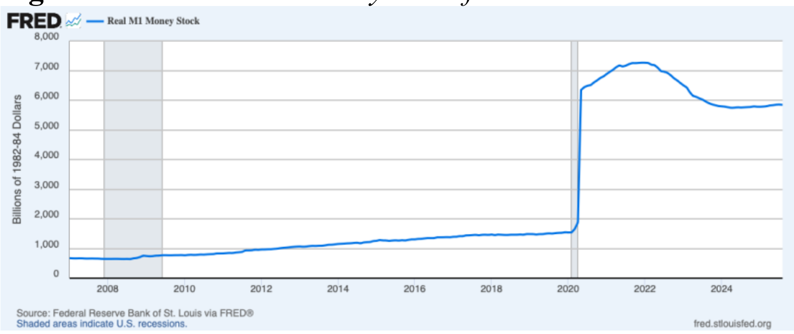
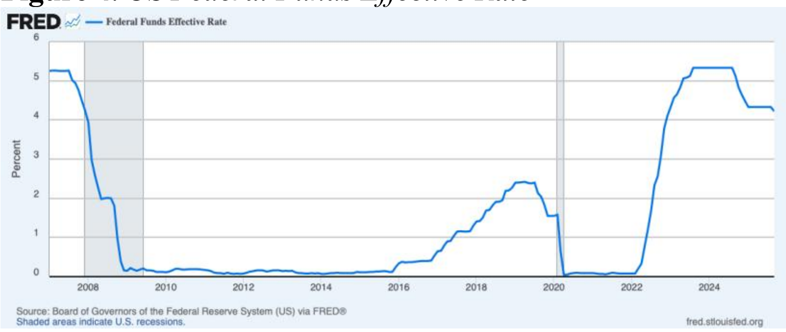


Figure 4. *US Federal Funds Effective Rate*



Please note the two grey periods appearing in Figures 3-6, these are two recessions at 2008 and 2020, the first one was a longer duration compared to the second.

Figure 5. *US Consumer Price Index "CPI"*

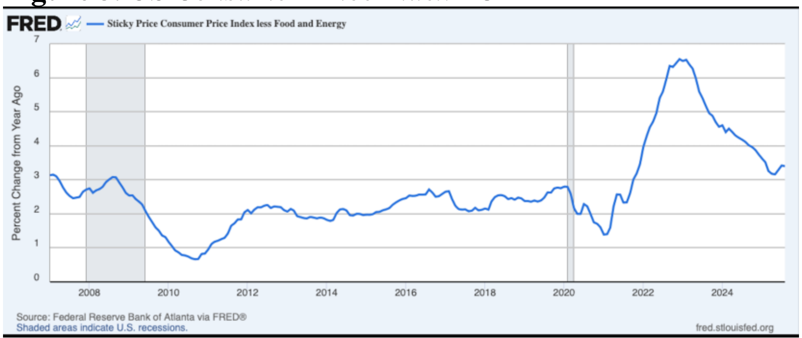


Figure 6. *Unemployment*

Figures 5 represents one of the major outcomes of the changes induced by the FRB as felt by citizens as they purchase goods and services. The data in Figure 6, is influenced by the changes made by the FRB for the values of Figure 3 and 4. Note that between 2007 to 20243 the US encountered two recessions (shown in grey in the four Figures of 3-6. The histories shown in Figures 3-6 are important to remember as we make comparisons of key USA indicators with the USA KEI history of Table 1.

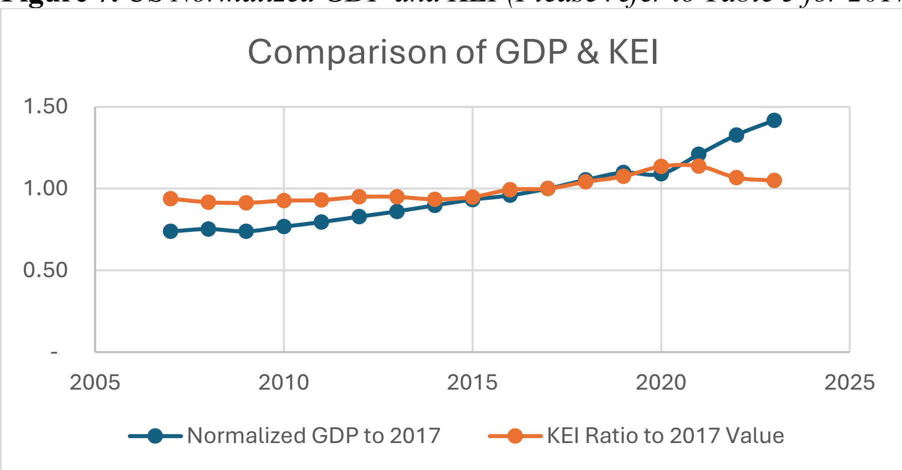
It is important to see what the changes introduced in by the FRB (Figures 3 &4) as it responds to undesired trends in the CPI and Unemployment in figures 4 & 5 thus triggering the FRB actions for changing M1 and interest rate (Figures 3 &4).

Comparison of Key Economic Data with Estimated KEI for the USA

In this section we compare KEI time change compared to key economic indicators. To make these comparisons, we normalized the values to the value of each parameter in 2017.Thus enabling the comparisons of the ratios of the parameters. Please refer to Table 5 found later in the section where the results of the comparisons are discussed.

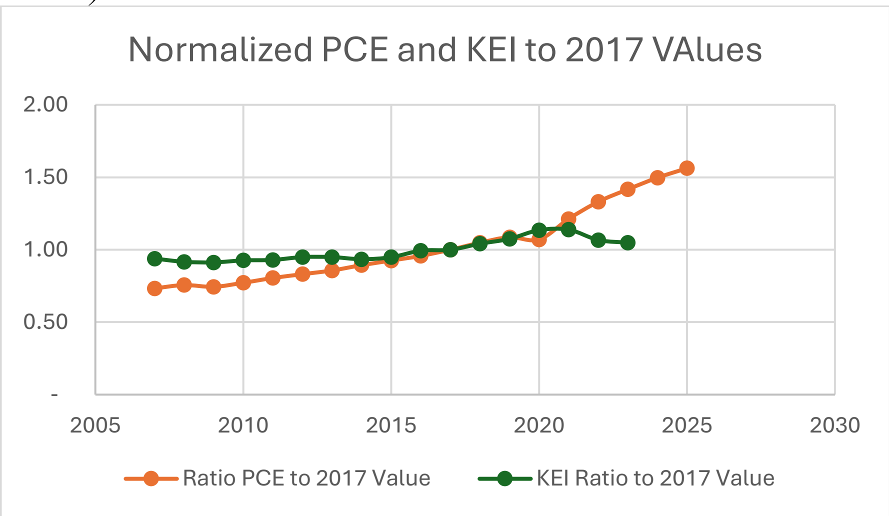
Figure 7 covers the comparison of KEI to GDP. Figure 8 shows the comparison of KEI with PCE Personal Consumption Expenditure, Figure 9 shows the KEI comparison with the Industrial Production Total Index.

Figure 7. *US Normalized GDP and KEI (Please refer to Table 5 for 2017 values)*



In Figure 7, one observes that KEI ratio to its value at 2017 was higher than the ratio of GDP in the same period this period includes the long recession and the slow recovery of the economy from that recession. From 2014 to 2020 we see that the two ratios were growing nearly to the same amount> Following 2020, it appears that GDP grew must faster than the average hourly wages in this period. There could be a large influence due to evolution associated with new innovations. We can see from Figure 4, the larger interest rate compared to that prior to 2020 and from Figure 6 the decrease in the unemployment. The latter effect can be signal for slower increase in the wages.

Figure 8. *US PCE & KEI normalized to 2017 (Please refer to Table 5 for the values in 2017)*



The behavior of PCE in comparison to KEI is shown in Figure 8. The GDP trends remain consistent across the three periods noted in the discussions of the KEI-GDP comparisons

Figure 9. *US Comparison Industrial Production Total & KEI Normalized 2017 values. (Please refer to Table % for the values in 2017)*

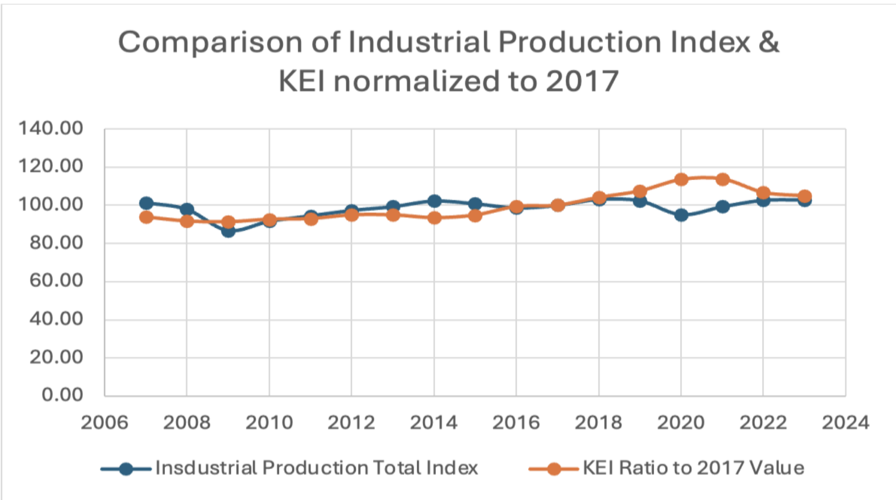
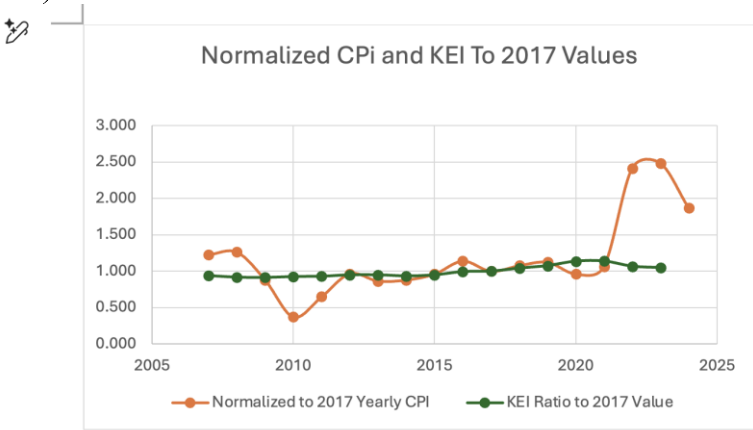


Figure 9 exhibits different trends compared to the comparisons of the DP / PCE to KEI of figures 7 and 8. The higher values of the Industrial Production Total before the 2008 recession and after the recovery of 2014, but the recession of 2020 though was brief it pulled the production down significantly.

Figure 10. *US CPI & KEI Normalized to 2017 (Please refer to Table 5 for the values in 2017)*



From Figure 10, one notes the drop in KEI in 2010 and in 2020, post the recessions. The high value of the CPI post 2021, reflects the high interest rate _ please refer to Figure 4.

One notes that the values in Figures 7-10 uses averaging for each year, and there is an influence in the histories associated with this averaging process.

An important comment about the Average Electricity Price AEP, that it is influenced by importation of gas, oil and pressures to reduce CO2 affecting coal plants as well as the introduction of Renewable Energy (wind and solar).

It is useful to review the population and the working population as well as the Retirees age 65 and up. Please refer to Figure 11 before Figure 12 is introduced. (Please refer to the overall summary of the results Table 5, for the values in 2017)

Figure 11. *Normalized Population, Working Persons and Aged 65 yrs &+ (Please refer to Table 5 for the values in 2017)*

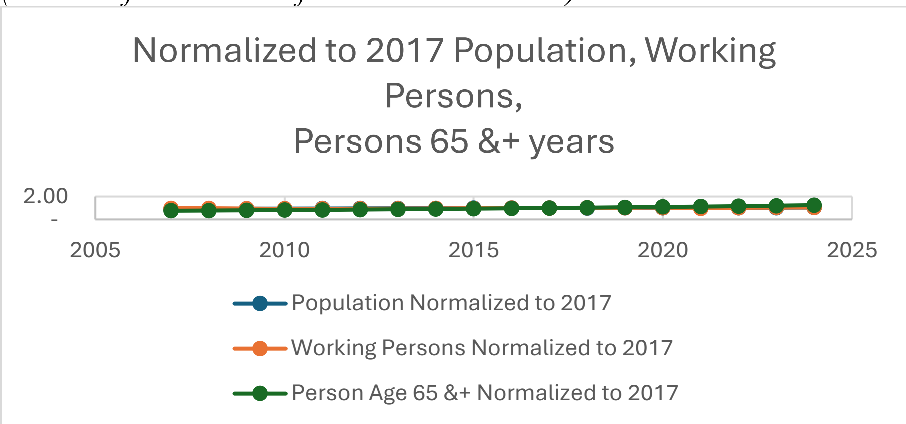
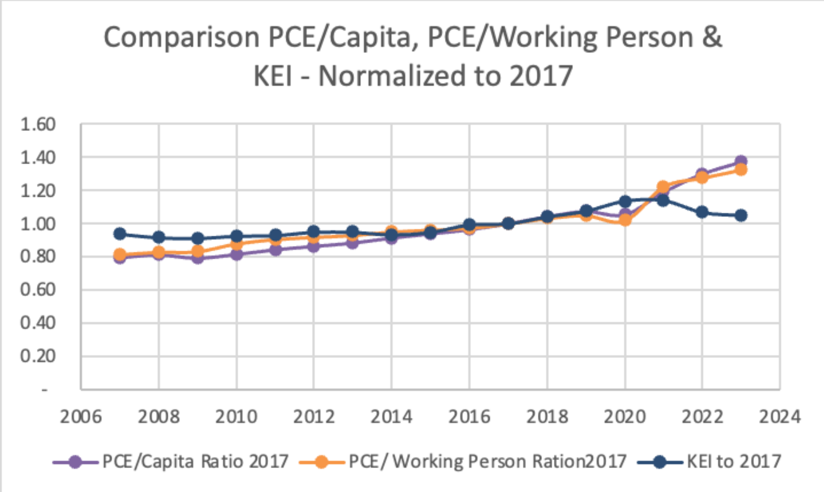


Figure 12. *PCE per Capita & KEI Normalized to 2017 (Please refer to Table 5 for the values in 2017)*



The comparison in Figure 12, show narrower differences compared to all the previous comparisons. This reflects the larger influence of the inflation on the commonly used economic indicators.

Discussion of the Comparisons

Table 6 Summaries the comparisons for the US for years 2007 to 2024.

Table 6. *Overall Summary of the Comparisons*

Figure #	8	9	100	10		11	11	12	12
Units	GDP Billion $	PCE Billion $				Population Thousands	Working Persons Thousands	$/per Capita	$ per working Person
2017 Value	19,612	13,291	100	2.65%	191.07	326,860	195,789	40,662	67,882
Year	Normalized GDP to 2017	Normalized PCE to 2017	Normalized Industrial Production Total Index	Normalized to 2017 Yearly CPI	KEI Ratio to 2017 Value	RATIO POPULATION To 2017	Working Persons Ratio to 2017	PCE/ per Capita Ratio to 2017	PCE Working Person Ratio to 2017
2007	0.74	0.73	1.01	1.23	0.94	0.99	0.98	0.79	0.81
2008	0.75	0.76	0.98	1.26	0.92	0.97	0.98	0.81	0.83
2009	0.74	0.74	0.87	0.88	0.91	0.96	0.95	0.79	0.83
2010	0.77	0.77	0.92	0.37	0.93	0.98	0.93	0.81	0.88
2011	0.80	0.80	0.95	0.65	0.93	0.98	0.93	0.84	0.91
2012	0.83	0.83	0.97	0.97	0.95	1.00	0.94	0.86	0.92
2013	0.86	0.86	0.99	0.87	0.95	1.00	0.95	0.88	0.93
2014	0.90	0.89	1.02	0.88	0.93	0.98	0.96	0.91	0.95
2015	0.93	0.93	1.01	0.96	0.95	1.00	0.98	0.94	0.96

2016	0.96	0.96	0.99	1.14	0.99	1.05	0.99	0.96	0.97
2017	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
2018	1.05	1.05	1.03	1.08	1.04	1.01	1.01	1.04	1.03
2019	1.10	1.09	1.02	1.12	1.08	1.01	1.02	1.07	1.05
2020	1.09	1.07	0.95	0.96	1.14	1.02	1.04	1.05	1.02
2021	1.21	1.21	0.99	1.06	1.14	1.02	0.97	1.19	1.22
2022	1.33	1.33	1.03	2.41	1.07	1.02	1.02	1.30	1.28
2023	1.42	1.42	1.03	2.48	1.05	1.03	1.04	1.37	1.33
2024	1.42			1.87		1.04	1.05	1.44	1.37
2025						1.05	1.05	1.49	1.42

The well-known economic parameters that are used extensively in economic studies and reviews have been compared with estimates for the KEI. Economic parameters often reflect a time lag due to shifts in aggregate demand and supply, which are shaped by numerous micro-level factors. Despite this, they help economists guide policymakers, especially during periods of instability.

The newly introduced KEI is related to the variations of the earnings of the working population which on the aggregate plays a dominant effect in the nation's production. In addition, the changes in the average electricity price, is also subject to the means of producing electricity. One should note the effect of innovation in boosting the production of both services and manufacturing again this comes with higher wages. The wage increase lags some time from the start of the implementation of innovation due to information dissemination and trainings. On the electricity side, also new innovations lead to lower production costs for electricity. The regulatory measures also influence the wages, and the electricity production costs

The Confidence Level in the Obtained Results

The author acknowledges that he did not have any means to assess the accuracies of the values of AHW and AEP that he obtained from the EC for Europe. He notes that the fact that the data for the US were only the last years since 2007. He can attribute that historical data before 2007 were not in enough detail that is suitable for the methodology that was developed by BLS. An additional comment from long experience in the construction industry, always price data had some tolerances, and it was the experiences of the veteran's that helped in taking the final calls for pricing., to minimize the risks of bids. Then, all measures are taken to stay withing the projected cost under execution. So the answer to the question about the accuracy of the calculated KEI, the author used **the data produced by the institutions that possess all the talent and means to collect, analyze the data, that produce the best representative data**. Please refer to the acknowledgement later in the paper.

KEI for Other Countries & Comparisons of KEI versus GKI results

The data uses for the estimates of KEI in the USA and Europe were obtained from public sources that are trusted and can be labeled as dependable. Though as was noted earlier there could be some small effects for use of different methodologies. When the author wanted to address other countries (outside the USA and 27 original EU countries- Europe), he faced of lack of what would give him the same confidence level. In this section, he reports on some of his endeavors and warns that the obtained KEI values could have large differences with the true KEI values. Because in several instances the author got data from different sources and was not sure of the accuracy, he opted to delete the values of the AHW and AEP and when he only could fine Income per hour IperH. For these situations the calculated KEI is in brackets and can be only interpreted as tentative, omitted

Table 7. *Estimates for KEI – Other Countries (2023)*

Country	Year	Average Wage /h AHW $/h	Income/h IperH $/h	Avg. Elec. Price $/hAEP	KEI
Japan	2023	*		*	[77.50]
Mexico	2023	*		*	[59.40]
Canada	2023	*		*	[278.10]
Australia	2023	*		*	[131.39]
South Korea	2023	*		*	[195.06]
Finland	2023	*		*	[137.31]
Hungary	2023	*		*	[83.26]
China	2023		*	*	[90.47]
Türkiye	2023	*		*	[114.6]
Egypt	2023		*	*	[68.97]
Nigeria	2003		*	*	[33.84]

The brackets are used to stress that the calculated values are tentative and for that reason the values ed. were used in their calculations were omitted. Please note that in some instances the Income per hour was used I lieu of the wage, as the date for the wage was easily found. Re is a spread of the ratio of the wage to the income among various countries.

The author decided to explore how the KEI results compare with indications from the GKI recently developed. To note that the two have completely different formulations. The reader is referred to how the annual GKI is prepared and there are indications that parts of the GKI methodology may be subject to change. This is quite understandable given the nature of the topic. Table 8 contains the comparisons. The author opted just to enter the readily available data in the table. For the KEI values the reader find the value in the table of the paper. For the GKI they are obtained from the dashboard of the GKI. The author decided to use the GKI of 2024 versus the KEI for 2023. No significant effect that may influence the indications that can be withdrawn. with respect to the difference in time.

Table 8. *Comparison of KEI Estimates versus GKI for select group of Countries*

Country	Table	KEI	order 2	order I	GK.I Score	GK.I Ranking
Sweden	3	399.00	2	1	68.28	**1**
Finland	*5* [137.31]	[137.31]	12#	2	*67.99*	*2*
Switzerland	3	351.40	4	3	67.84	**3**
Denmark	3	365.50	3	4	66.99	**4**
Netherlands	3	239.90	6	5	66.84	**5**
Luxembourg	3	224.10	7	6	66.48	**6**
USA	1	200.53	9	7	66.24	7
Norway	3	578.90	1	8	65.77	**9**
Belgium	3	318.40	5	9	64.69	**11**
Canada	*5* [278.10]	[278.10]	6#	10	*64.52*	***12***
Germany	3	217.70	8	11	63.66	**16**
Australia	*5* [131.39]	[131.39]	12#	12	*63.45*	*17*
South Korea	*5* [195.06]	[195.06]	10#	13	*62.25*	***21***
France	3	183.00	10	14	61.58	**23**
Portugal	3	117.80	13	15	61.22	**25**
Spain	3	166.40	11	16	60.66	**28**
Italy	3	156.80	12	17	59.08	**32**
Hungary	7 [83.26]	[83.26]	14#	18	*56.19*	***37***
Bulgaria	3	62.90	15	19	56.13	**38**
Greece	3	99.00	14	20	52.13	**47**
Tiirkiye	*5* [114.6]	[114.6]	14#	21	*49.21*	***59***
Mexico	5	[59.4]	15#	22	*46.11*	***76***
Egypt	*5*	[68.97]	15#	23	*44.02*	**90**
Nigeria	5	[33,84]	16#	24	*40.27*	**103**

KEI Values in brackets are tentative as indicated in Table 8.
In the order, a mini ranking is introduced order1 for KEI and Order2 for the GWI (among 24 countries). Noting the GWI ranking in the last column, is the ranking among 173 countries.

KEI and GKI produced comparable trends, and recognizing the distinctive bases of the two indices the comparison gives credence to bot

Additional Supplementary Information for the USA

In this paper the main thrust was devoted to the application of the Human Capital and Energy in driving the economy. The working population and the energy consumed forms a significant role in the production of services and manufactured products. On the consumption side the households constitute the ultimate beneficiaries of the results of the working population. Thus, we address the population and the Employment working percentage of the population as well as the unemployment Rate Figures 11, 16and 6. In addition, we complement the main information included in the previous sections by

Figures 13, 14 and 15, showing the Imports, net Exports of goods and services and lastly the Personal Savings Percentage Rate.

Figure 13. *Imports of Goods and Services*

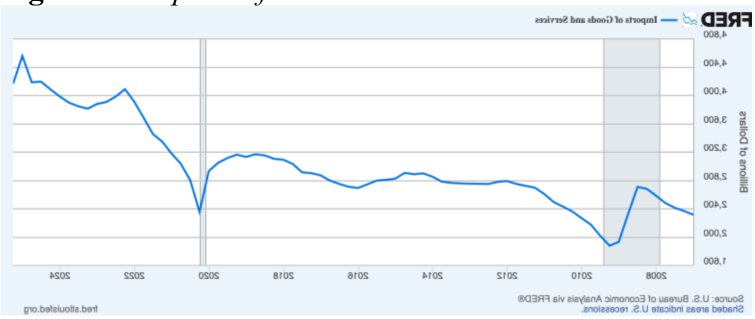


Figure 14. *Net Exports of Goods and Services*

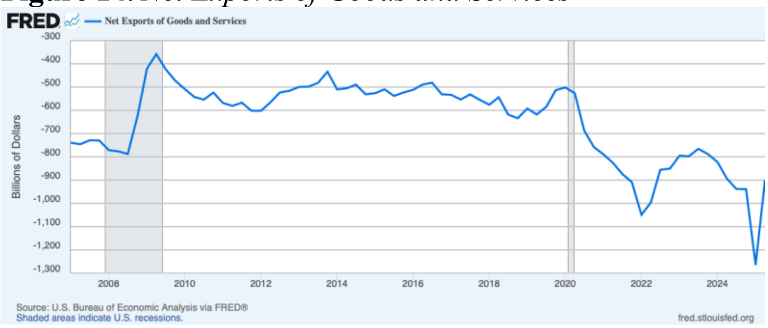
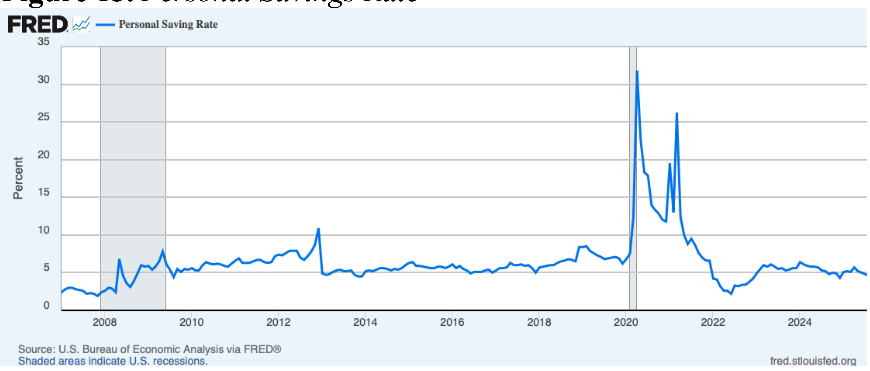
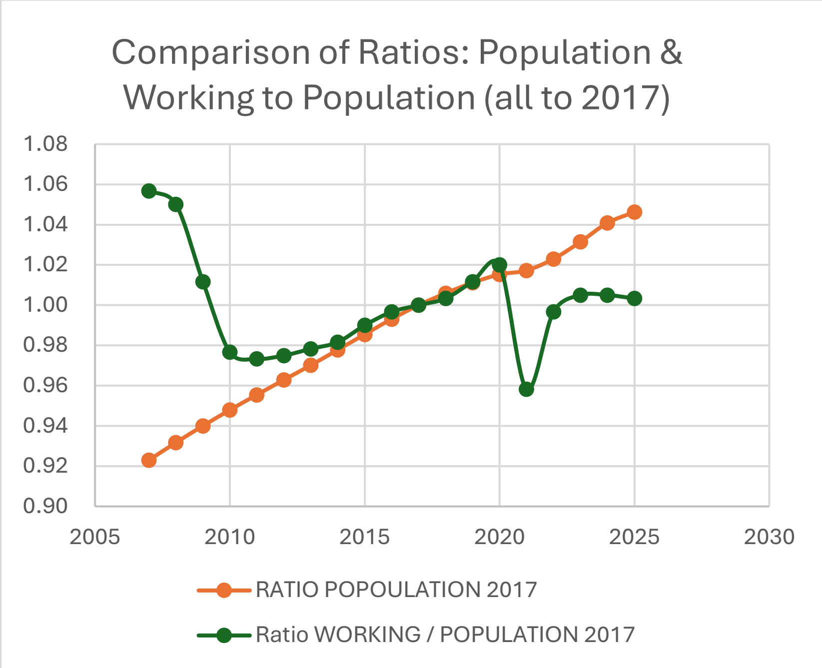


Figure 15. *Personal Savings Rate*



Figures 13 to 15 show additional factors that affect the supply and demand in the economy of the USA that have indirect influence on the data used in the estimate of the KEI. Further the working population changes are shown in Figure 16.

Figure 16. *Ratio of working Population to Population Growth 2017 Population 326 million and Working 195 million*



From this figure one sees the drop of the employment post the two recessions, it takes time to regain previously recorded employment prior to the recessions**.** The taxation has also indirect effect.

Additional Insights into KEI

OECD Countries

Following the previous sections, the author sought updated salary data from additional sources. After reviewing several datasets for the Nations average annual salaries OECD (n.d.) and average electricity prices (petro), he decided to extract data for (2023-2025) respectively for 37 countries. He supplemented these by populations in these countries. Please refer to Table 9.

Table 9. *KEI for OECD Countries*

#	Reference area	(2023-2024) AHW - USD, (PPP Conveted 2024)	(2024-2025) AEP USD/kWh	KEI	Population
1	Australia	36.8	0.255	144.2	26,974,026
2	Austria	38.9	0.342	113.7	9,113,574
3	Belgium	39.5	0.402	98.3	11,758,603
4	Canada	36.1	0.123	293.7	40,126,723
5	Chile	*19.9*	0.212	93.7	19,859,921
6	Colombia	*15.0*	0.202	74.4	53,425,635
7	Costa Rica	*21.4*	0.169	126.4	5,152,950
8	Czechia	19.6	0.353	55.7	10,609,239
9	Denmark	37.9	0.358	105.8	6,002,507
10	Estonia	20.1	0.286	70.2	1,344,232
11	Finland	31.0	0.182	170.3	5,623,329
12	France	31.4	0.277	113.5	66,650,804
13	Germany	35.8	0.404	88.7	84,075,075
14	Greece	16.6	0.247	67.3	9,938,844
15	Hungary	17.6	0.109	161.2	9,632,287
16	Iceland	46.8	0.172	272.0	398,266
17	Ireland	31.5	0.444	71.0	5,308,039
18	Italy	26.4	0.419	63.1	59,146,260
19	Japan	25.7	0.23	111.7	123,103,479
20	Latvia	22.9	0.28	81.7	1,853,559
21	Lithuania	26.8	0.271	99.1	2,830,144
22	Luxembourg	48.8	0.252	193.8	680,453
23	Mexico	10.7	0.107	100.4	131,946,900
24	Netherlands	39.0	0.286	136.5	18,346,819
25	New Zealand	32.4	0.206	157.2	5,251,899
26	Norway	39.0	0.155	251.8	5,623,071
27	Poland	22.3	0.231	96.7	38,140,910
28	Portugal	20.6	0.234	87.9	10,411,834
29	Slovak Republic	18.4	0.21	87.6	5,474,881
30	Slovenia	31.3	0.226	138.6	2,117,072
31	SOUTH KOREA	26.4	0.126	209.3	51,667,029
32	Spain	28.4	0.246	115.4	47,889,958
33	Sweden	31.1	0.233	133.5	10,656,633
34	Switzerland	45.3	0.364	124.5	8,967,407

35	Türkiye	*24.6*	0.067	367.3	87,685,426
36	United Kingdom	32.9	0.399	82.6	69,551,332
37	United States	43.0	0.182	236.1	347,275,807
			37 COUNTRIES		1,384,614,927
				Global Population	8,229,745,543

The data of the AHW was computed from the original data (OCED (n.d.)) based on 1920 hours working hours per month. The author chose the salary from the noted source with adjustment of the salaries to USD PPP 2024. The two factors represent some uncertainties in the values used to estimate the AHW in Table 10. But the author wanted to illustrate the possible effects of the full- time hours that may not be the same in all countries, as well of the exchange rates variability in the salaries when adjusted to a common currency. The electricity prices from Global Petrol Prices (n.d.) was in USD. It is worth noting that the data of the average electricity prices in Global Petrol Prices (n.d.) include prices for the consumers AEP which have been included in Table 9, plus average electricity prices for industrial users. The ratio of the former o the latter, varied among the 37 countries 207%, 178%, 177% (for Iceland, South Korea, Estonia) to. 47%, 50% (Tutkye, Mexico). This reflects the strategies among different countries for offering incentives to industries, or vice versa. The Last column in Table 9 shows the country population, and one can see the effect of the population on the AHW associated with a large % percentage of lower paying jobs, that pushes the AHW to lower values even if the knowledge level in segments could be relatively high. The subsidies and or the taxes that are applied to the Electricity prices in different countries would have an influence on the values used for the AEP when estimating the KEI.

Countries with large populations end up with lower KEI because of the spread in the wages compared to smaller countries. This led the author to examine the KEI for countries with the largest populations –Table 10.

KEI in Populous Countries

Table 10. *Knowledge Energy Index (KEI) among Countries with Large Populations*

					GKI	GKI
Country	**Table #**	**KEI**	**Order 2**	**Order 1**	**Score**	**Ranking**
Sweden	4	399	2	1	68.3	1
Finland	7	[137.31]	12#	2	68.0	2
Switzerland	4	351.4	4	3	67.8	3
Denmark	4	365.5	3	4	67.0	4
Netherlands	4	239.9	6	5	66.8	5
Luxembourg	4	224.1	7	6	66.5	6
USA	1	200.53	9	7	66.2	7
Norway	4	578.9	1	8	65.8	9

Belgium	4	318.4	5	9	64.7	11
Canada	7	[278.10]	6#	10	64.5	12
Germany	4	217.7	8	11	63.7	16
Australia	7	[131.39]	12#	12	63.5	17
South Korea	7	[195.06]	10#	13	62.3	21
France	4	183	10	14	61.6	23
Portugal	4	117.8	13	15	61.2	25
Spain	4	166.4	11	16	60.7	28
Italy	4	156.8	12	17	59.1	32
Hungary	7	[83.26]	14#	18	56.2	37
Bulgaria	4	62.9	15	19	56.1	38
Greece	4	99	14	20	52.1	47
Türkiye	7	[114.6]	14#	21	49.2	59
Mexico	7	[59.40]	15#	22	46.1	76
Egypt	7	[68.97]	15#	23	44.0	90
Nigeria	7	[33.84]	16#	24	40.3	103

From Table 10, one notes that countries with very low electricity prices end up with large KEI. This in many cases is due to arterially low prices due to subsidies. An issue that the IMF raises. The lower salaries in many of the highly populous countries reflect a high portion of the population is engaged in low knowledge level jobs. Please note the US and Japan are two countries that appear in Tables 8 & 9 (different AHW values, different source of the data and different year).

KEI for Select African Countries

Table 11. *KEI for Select African Countries*

#	Country	Avg Monthly Wage (USD)	AHW USD/h	AEP USD/kWh	KEI	Population
1	Morocco	1,910	11.94	0.119	100.32	38,430,770
2	South Africa	1,712	10.70	0.192	55.73	64,747,319
3	Seychelles	1,517	9.48	NA		
4	Kenya	1,089	6.81	0.22	30.94	57,532,493
5	Namibia	957	5.98	0.137	43.66	3,092,816
6	Gabon	925	5.78	0.205	28.20	2,593,130
7	Nigeria	729	4.56	0.036	126.56	237,527,782
8	Rwanda	628	3.93	0.201	19.53	14,569,341
9	Zimbabwe	600	3.75	NA		
10	Burundi	568	3.55	NA		

11	Libya	482	3.01	NA		
12	Zambia	339	2.12	0.023	92.12	21,913,874
13	The Gambia	255	1.59	NA		
14	Ethiopia	165	1.03	0.006	171.88	135,472,051
15	Sudan	61	0.38	0.01	38.13	51,662,147
					Samples Sum	**627,541,723**

Source: salaryexplorer.com via InvestGuiding

Table 11 includes Nigeria and Ethiopia both previously appeared in Table 9**.** The very low prices of the electricity appear to be questionable. The KEI of Morocco and South Africa represent again the effect of lower electricity price on the KEI.

Why it is Difficult to apply the KEI for Developing Countries

Two major difficulties are behind getting accurate data for AHW and AEP that needed to evaluate KEI., beside the degree of the integration of the developing country in the world economy. Many of the developing countries suffer from Shadow Economy/Parallel Economy, Loayza, N.V. (1996), and Chen, M.A. (2012) with resulting negative economic effects These are the large parentage of the shadow economy and secondly the high subsidies of electricity. These two factors would render the obtained KEI as not realistic. This would be unfair representation of for these countries.

The first factor can be demonstrated by the examples in Table 12.

Table 12. *Examples of how large Shadow Economy in Some developing Regions*

Region	**Informal employment share (of total employment)**	**Informal economy / informal sector as % of GDP or formal economy**
Sub-Saharan Africa	~85.8% of employment are informal workers.	Informal economy estimated 34% of GDP in some estimates for region.
Asia & Pacific (developing/emerging)	~68.2% of employment informal.	Informal economy for some countries 30% of GDP (EMDEs) on average.
Latin America & Caribbean	~40% of employment informal (emerging/developing).	Typical informal economy share ~30% of GDP in many countries.
Middle East & North Africa (MENA)	~64.9% of employment informal (2022 data) in the region.	Informal economy (output) in the region estimated between ~25% of GDP.
Northern Africa	~48% of nonagricultural employment informal (2000s data).	Informal sector incl. agriculture ~40% of GDP. (Estimates vary)
Transition/Eastern Europe & Central Asia	~25.1% of employment informal (Europe & Central Asia average).	Informal sector including agriculture averaging ~19% of GDP in one dataset.

*World Bank "Informal Economy Database" – includes data for up to 196 economies for informal employment and output World Bank (n.d).

Notes & caveats:

- *"Informal employment" refers to workers in jobs lacking formal contracts or social protections. The employment share is easier to estimate than exact GDP contribution.*
- *GDP/informal economy shares are model-based estimates; for example, one study estimates for EMDEs that the informal sector accounts for nearly one-third of GDP.*
- *Variations are large across countries within regions. For example: in Sub-Saharan Africa estimates ranged from ~22% up to ~72% of non-agricultural employment being informal.*
- *Agricultural employment often has very high informality. Excluding agriculture typically reduces the employment share somewhat.*
- *Definitions differ: "informal sector", "informal employment", and "shadow/underground economy" overlap but are distinct. Measurement approaches vary (e.g., labour surveys, currency demand method, electricity consumption method).*
- *These numbers provide broad regional averages useful for comparisons, but country-specific data will vary and may have higher precision.*

Additional data can be found in UNCAD16 (2025).

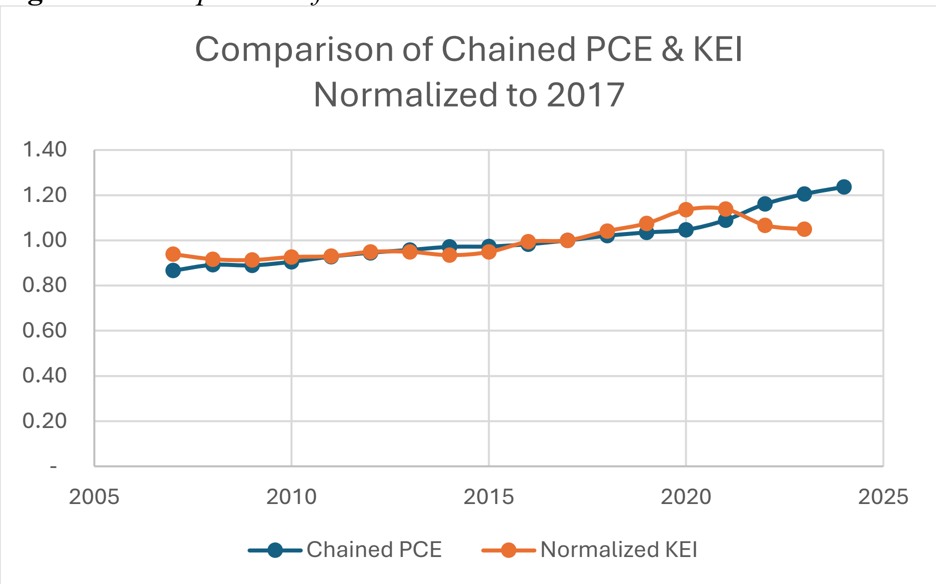
For several developing countries, they are plagued with internal political strides and in some cases outside conflicts. These conditions lead to slow integration in the global economy. In many cases, the problems cause real difficulties to obtain dependable data for both AHW & AEP not achievable.

Fortunately, the UN is helping in many ways one major activity is taking plkace is training staffs from developing countries on systems including digitalization that is ewxpanding into AI, UNCAD16 (2025).

Effect of Inflation on the Comparisons

The author asked the question what inflation could alter the comparisons of US economic indicators in the comparisons of KEI to the economic indicators, in Figure 16, the KEI is compared to Chained PCE (both normalized top 2017)

Figure 17. *Comparison of Normalized Chained PCE versus KEI*



The comparison in Figure 17 shows an apparent better comparison compared to previous comparisons in Figures 7-12 (for different parameters).

Different Sources of Data

The author raised the question if the data he uses comes from a different source, what could be the effect on KEI. He turned to the US Social Security (n.d.) versus the BLS (n.d.) that was presented earlier. Table 2 shows, the differences in the calculated KEI.

Table 13. *Comparison of KEI calculated based on BLS and SS Wages*

Year	SS Index $/Y	SS $/h	Average Hourly Wage AHW $/h	Average Electricity Price AEP $/kWh	Knowledge Energy Index Ratio AHW/AEP	KEI based on SS Hourly Rate
2007	40,405.48	21.04	20.91	0.12	179.4	175.4
2008	41,334.97	21.53	21.56	0.12	175.2	179.4
2009	40,711.61	21.2	22.17	0.13	174.4	163.1
2010	41,673.83	21.71	22.58	0.13	177.0	167.0
2011	42,979.61	22.39	23.03	0.13	177.7	172.2
2012	44,321.67	23.08	23.51	0.13	181.4	177.6
2013	44,888.16	23.38	23.96	0.13	181.4	179.8
2014	46,481.52	24.21	24.46	0.14	178.6	172.9
2015	48,098.63	25.05	25.01	0.14	181.2	178.9
2016	48,642.15	25.33	25.65	0.14	189.9	181.0
2017	50,321.89	26.21	26.31	0.14	191.1	187.2
2018	52,145.80	27.16	27.1	0.14	199.0	194.0
2019	54,099.99	28.18	28	0.14	205.4	201.3
2020	55,628.60	28.97	29.36	0.14	217.0	207.0
2021	60,575.07	31.55	30.61	0.14	217.5	225.4
2022	63,795.13	33.23	32.26	0.16	203.9	207.7
2023	66,621.80	34.7	33.72	0.17	200.5	204.1

The KEI estimate's accuracy is dependent on how accurate the Average wages and Average Electricity price are. The uniformity of the methodology used in deriving these values are key to getting dependable KEI. This was seen when the other countries were investigated.

The author did not except the degree of agreement of the KEI versus the GKI that are shown in Table 6. As the two indices are based on completely different methodologies. The trends of the two methods appear to close and for the cases where there are significant differences, some further investigation may be in order. KEI is just born by the author – and is merely – his own, but as it picks interest, improvements will come. The KEI prioritizes the **application** of knowledge.

In the big picture establishing that Knowledge has grades as BLS created the Job Levels is very significant.

Commentaries

Under this section, the author shares some of his experiences that tie with the previous contents of this paper.

HC – Management of Technology & Technology Transfer

Safwat HH and Oweiss IM (2002), discussed how Management of Technology gives impetus for Economic Growth. Developing countries aim to boost their economies and they seek bring new industries, the new industries could have new technologies. They would investigate the closeness or the gap between the knowledge base they already have and decide of what to do in HC in preparation for receiving the new industries, The government would need to identify the incentives it could offer for the birth of a new industry. In the developing country, if a local company wants to partner with a foreign company in partnership or under a licensing arrangement the two companies need to reach a mutually agreeable agreement for technology transfer, The Technology Transfer agreement sets the foundation for how the new technology would be practices in the receiving company.

When a company ”a” in a country, wants to adopt a new technology, and seeks to partner company “b” with, which mostly is from a foreign country that possess the sought technology, the two sides formulate a plan for the cooperation whose core is the transfer of technology agreement or plan please refer to Safwat HH and Higgy HR (1994), this can be viewed as part of boosting the HC of company a. In numerous instances, a consultant plays a pivotal role in facilitating discussions and negotiations between companies a and b. For further reference, see Safwat HH (2002), "The Role of the Consultant."

KEI as Tool to Identify Possible Countries in which to expand

In several instances, a company considers expanding in foreign countries. When this comes up, a good starting point is to look at the KEI of that country. This gives a first signal for the fit of foreign country, or countries. Then the appropriate due diligences follow and subsequently detailed survey that focus on specifics and the partnering, if partnering with a local firm is to be considered.

The KEI Relevance for Promoting HC towards Growth

The nation’s KEI tables suggest for leaders in nations implement strategies that support HC hl to increase knowledge (that leads to increase wages), while also targeting reduction of electricity costs. This is the key to promote growth and increase the competitiveness of the nation among other nations.

Artificial Intelligence and Knowledge & Energy (AI – K&E)

The author started looking into Artificial Intelligence in 1988, at that time he had decided to move to project management from his previous position as a manager of a highly specialized technical group. In that group, he was building on aa specialization he got when he worked on his second Ph.D. and evolved to be among world renown highly valued experts. He reached a high reputation and was involved in sophisticated diagnosis of difficult operational problems in nuclear power plants between 1972 - 1988. In 1987, as he was to ready to leave this position, he decided to investigate the then AI – the Expert System Software. In that days, the available software used rules approach, and the developer of the application had to get used to a different rule-based logic, in contrast to the computer languages such as Fortran and the likes. He took a course in neural working and called on an IT analyst to partner with him to record the dialogue of questions and answers to populate the expert system. Unfortunately, the process was quite cumbersome and took long time, so the attempt was halted.

As the goal of the author was to preserve the knowledge he and his colleagues had, they published Safwat HH (1992), and, Safwat HH, Arastu AH and Morcos NW (1993). These provided the bases for performing a diagnostic but not in a form of a software.

In recent years AI gained very large momentum and now it is the most relevant technology of our time, basically there is tremendous shift from the rules-oriented software. Today's AI basically is a field of computer (Information Technology) focusing on creating systems that can perform "tasks" typically require human intelligence. Very quickly, the reader recognizes "tasks" – and the central theme of this paper the knowledge - energy pair. The KEI reflects the high value of the knowledge component versus the energy. If one can reduce the knowledge application in a task, and even the energy increases several folds, the result will render commercial value as there is very large room for substitution of labor hours by computer kWh's.

AI requires investments in Hardware (chips) and software to enable the efficient digital search on a large scale, and then tailor-made software for use in different industries. Then comes the required training of the users of the software.

Now, we are witnessing how EI is fast growing and how its required electricity for powering data -centers is shaping the electric industry. Further, we can see the growing relationships between IT and electricity companies, in energy related conferences where now digitization, smart meters, AI have become dominant in the energy conferences.

Reflections on Current Global State

From several figures of the USA economic indicators versus KEI, one realizes that following a recession, the wages drop and it takes long time to recover while the economy grows at good paste. The interest rate set by the FRB influences this as can be seen following the recession of 2020.

Thus, we recognize what is transpiring in the US economy in 2024 -2025 is affected by the recession of 2020 and the higher interest rate the FRB is keeping combatting inflation which is still holding a high rate. With the size of the US economy being the largest market for many goods the trade with other countries and the currency major exchange rate come into play.

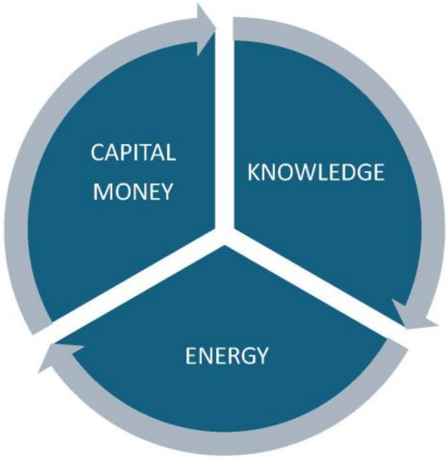
On the other hand, two major factors are at play, The first one Global Zero emission programs being pursued globally to reduce GHG (Green House Gases), primarily Carbon Dioxide towards reducing fossil fuel use, to curb global warming. This has effects on investments and operations of the electric systems in various countries. Shocks can be felt on the existing assets in the energy and the electrical industries. The KEI underlines the major goal of reducing the electricity price. In parallel, the growing adoption and acceptance of AI as a tool to improve productivity is taking hold, shift of new jobs aligned with AI growing industry on the side of hardware. (chips) and software "Increase", as well as the use in different fields may cause increase in retraining but in the midterm and long term could result in decrease in jobs. The overall knowledge employment under AI will change. As these two major factors evolve, the transformations could be drastic and will have winners and losers. The effects on developed countries and developing countries will depend on the policies and priorities these countries will adopt for HC nourishment and development. KEI underlines the priority of enhancing knowledge.

Convergence of Knowledge and Energy

Based on Safwat HH (2022) and (2024) together with the KEI formulation presented in the previous sections, the author is now confident to contemplate that the application of knowledge has the same outcome that the application of energy produces. Further as there iare several energy forms with electricity representing the highest grade and most valuable as noted earlier. One can argue that knowledge has different grades (remember the levels used by BLS noted earlier) and all of them are of higher grade than electricity as the KEI values reflect. This is a very important conclusion and demonstrates why mankind has converged to recent economies in most countries are dominated by services. Now we see the GDP of most countries has 70 % - 75% of services. When one says different grades of knowledge, what counts is the influence of the application of the knowledge. In professional sports, a champion earns a premium award by applying superior knowledge and skill during their performance. One can see this observation when highly paid professionals are engaged. For the younger generations, they can see that advanced degrees (deeper / higher grade knowledge) lead to better compensation. By the same token, enterprises can see the premiums they can command in their offering with improved technologies based on innovation. The author is confident that the KEI represents a good step in establishing a new scale for knowledge with different types, with the focus on the knowledge application.

Figure 18 depicts the three pillars that are closely related and are behind all transactions in an enterprise as the author discussed in Safwat HH (2022) and (2023). This is also why the author used equations 1-3 originated in Safwat HH (2022) and now they resulted in the introduction of KEI in this paper.

Figure 18. *The Three Enablers – Means*



In recent developments in different industries, we can recognize how practitioners are now benefiting from leveraging the closeness of knowledge and energy.

What is Different in the KEI

Unlike the HC and IC models summarized in the they all are quite valuable forming theoretical and empirical approaches to understand and analyze factors that are essential in Economic Growth. Many well recognized economists have built on cumulative experiences since 1950's. The related literature to HC and IC as noted earlier marks an excellent progression. The KEI is coming from a distinctively different angle, it started from the extensive background of the author in Energy and his wide experiences in 45 years in various level of leading engineering and construction companies, including project development with the the emphasis on investments.

Thus, in Safwat HH (2022) and (2023) he built on this background to reach the knowledge-Energy pair and the capital-knowledge-energy trio. The latter is depicted in the schematic in Figure 18.

The KEI as formulated started from Business Economics. The author expanded the methodology of the noted references to Macroeconomics in this paper after continued thinking and consideration of what he learned in Thermodynamics as presented in Safwat HH (2024), when he realized that knowledge has high value compared to electricity as noted in this paper. The suggestions of the reviewers to the author to go deeper in HC and IC have been quite enlightening to him as he got to understand a lot of the valuable contributions of the esteemed economists to the Economic Growth Theory. That has enriched him further and will be useful for future endeavors. The author finally hopes that the KEI could open the Economic Growth Theory to the key factor of "Energy".

Trade Theory & Growth Theory

As was noted earlier the author had decided to exclude imports and exports. However, as he was urged by the reviewers to tackle the growth theory, he examined the close relation of the growth theory to the trade theory. He would like to note the work of his mentor in economics Oweiss, I.M. (1974) on the Petrodollars. Heckscher, E. and Ohlin, B. (1933), Krugman, P. (1979), Krugman, P. (1980), and Melitz, M. (2003) contributed to the evolution of the Trade Theory and one observes the relationship from these references. The author underscores the growth many of the countries that had large oil resources, whether. gil or gas, Saudi Arabia, Venezuela, Qatar, Algeria, UK, Norway, Indonesia Russia and UAE. How through trade these countries managed to develop and grow. For this reason, the author is inviting the economics community to include energy in both the growth theory and the trade theory.

Conclusions & Recommendations

The KEI is a <u>simple tool</u> that can be used by entities and nations as an indicator where they are compared to others. Though it took the author years to reach this index. The KEI can help in adopting policies that would increase competitiveness.

The author is satisfied that his search for a way to measure knowledge is successful, linking it to the energy unit kWh.

For the nation's KEI, it is suggested that establishing a uniform methodology for reporting both average hourly wages AHW and average electricity price AEP. This can be done under a UN organization with participation from different countries. This will be useful particularly for developing and least developed countries. KEI reporting will reveal the influence of subsides and taxes in possible undesired biases in the KEI estimates. The KEI shows why Knowledge and Energy are converging together in many industries as we see Energy & Intelligence taking hold.

Acknowledgements

The author dedicates this work to the late Economics Professor Dr. Ibrahim Oweiss from George Town University who passed away in November 2023. Professor Oweiss collaborated with the author since 1988 as noted earlier in the paper. Dr. Oweiss was instrumental in the joint effort that produced the first book in 2002. Dr. Oweiss inspired the author to take on further work building on the 2002 book.

The author wishes to acknowledge and express his appreciation to the excellent data sources of

- BLS Bureau of Labor Statistics https://www.bls.gov/
- BEA Bureau of Economic Analysis https://www.bea.gov/
- FRED Federal Reserve Bank St. Louis https://fred.stlouisfed.org/
- EU European Commission Statistics https://ec.europa.eu/eurostat

The data used in this paper were obtained from these sources. The author notes the data in these sources were very well organized and quite comprehensive. Without this data the completion of this paper would not have been possible.

The sister paper Safwat HH (2025) complements this work by covering US historical economic data from 971 to 2023. Further, the author notes a paper under the subject of knowledge as energy. is under preparation.

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