Correlation between Future Energy Systems and Industrial Revolutions

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Abstract

The last two to three centuries have witnessed humongous technological, socio-economic and environmental transformations which have laid precedence to the swift advancements in fields of sciences, engineering, medicine, business, and economics. While researchers focus on the productivity and economic growth potential and how subsequent industrial revolution paved the way for current contemporary lifestyle, very few analogies exist on the relationship between the intervention of the technology used and the implications as per energy management concerns during that period. The authors of this paper examine the impact of the changes in the industrial structure from the first to the third industrial revolution era (Industry 1.0, 2.0, 3.0), premised on the campaigns for cost-effective manufacturing and energy conservation throughput within the time frame, and how it transitioned to existing technological innovations. The article discusses energy issues and performance from the technology utilization perspective since the eighteenth century that has led to the present engineering practices or the resolve for change, through new means and technological approach. Different industrial practices which ushered the current anthropogenic situation are assessed, and critical strategies that are pivotal to drive current reforms, innovations and future ideas to see to the unstoppable realization of the Industry 4.0 ($I_4.0$) on a large, medium and small scale and the possible transition to Industry 4.0 plus and Society ($I_{4.}^{+}S$) are presented.

Keywords

Energy, Industry 4.0, Industry 4.0 plus and Society, Technology

1. Introduction

Global attention towards technological advancements and the trending concept of $I_4.0$ holds lots of potentials to cause socio-economic remould. Current evolutionary tendencies toward the adoption of Information Communication Technology (ICT) will bridge the gap between the effective interaction of man and machine steered by the Internet of Things (IoT), and capable of tackling environmental and work-related risks. Expert knowledge on large data management, cloud computing, sensor and actuation technologies, and artificial intelligence is securing the path towards breakthrough in advanced communication techniques, smart industry (through the use of cyber-physical systems), and energy conservation through power savings, generation technics, and new technologies, thereby reducing the atmosphere carbon emission level (Gilchrist, 2016). Past literature had focused on technical issues, such as techniques, type of technology, application and the opportunities which future technological development holds. A close observation of the industry 1.0, 2.0 and 3.0, conventionally known as the first, second and third industrial revolution, noticed a shift from one era to the other, through the support of technological innovations. However, we may without doubting say that, not all three transitions from the past occurred without ill-effects. This article looks at some of the critical issues concerning the fourth industrial revolution development and how its possible achievement will impact energy conservation through the technologies proposed to drive the whole concept. Hence, the research is a theoretical contribution to the pre-eminent changes that come with the new initiative of $I_4.0$, with focus on industrial relevance and social and environmental implications.

The authors' inclination attempts to provide a clear understanding of how technological trends in the past inspired the development of anew, to meet future demands. Thus, an overview of past technologies, starting from the first, second and to the third industrial revolution era, for energy generation, based on fossil fuel sources which in essence caused economic growth and flourishment, impacted negatively on the ecosystem. The section which follows, (2) is a brief review of the historical transformation since the pre-industrial age, giving inference to manufacturing practices, and energy conservative importance, from the past to current, and with regards to technology initiatives and implementation. Section 3 looks at the future and compares technological innovations with economic and environmental impact, based on carbon emission of selected countries and its' readiness to implement a modern and conservative approach to manufacturing especially from the perspective of $I_4.0$. Section 4 concludes the paper with an argument of what the future society may hold, premised on the successful implementation of $I_4.0$ and the transition to $I_{4.}^{+}S$.

2. The First, Second and Third Industrial Revolution.

2.1 Industry 1.0

The Industry 1.0 era, refers to the time when manual mass production had occurred in the nearly late eighteenth century. Water and steam-powered engines were the most useful technologies as at the time and employed in wide varieties of application; transportation, mining, printing, to name a few. The first industrial revolution started to take shape as new designs for agricultural farm extension tools made from iron were considered to substitute the existing tiresome processes and inefficient human efforts in farm operations. As such, encouraged the growth of steel companies preceding the war era of 1880's, followed by other dedicated needs to use iron more in buildings, railway tracks, bridges, boats, and machinery construction. Britain, within the late eighteenth and early nineteenth centuries, arguably was the period of the first industrial revolution, had coal and steel deposits for their consideration, and ample workforce to develop the engineering industry (Crafts, 2011). Also, based on their capability to manage the unlimited supply of precision, and highly standardized industrial equipment judiciously, unequivocally stimulated scientific inventions from 1750 to 1850. Hence, encouraged economic growth through a reduction in the cost of machinery, and invariably increased productivity in all facet of the manufacturing industry. Thus, bathed what today is called, the first industrial revolution (Robert C Allen, 2010). Although, the exploitation of coal during the first industrial revolution led to dramatic changes in their technological bearing. Other countries (Japan, Korea, etc.) with similar potential, as per resources and population did not contest in the developmental trend: "confidence, will-to-act, and presence of technological expertise is an essential requirement to frame the next industrial revolution," as did Europe in the middle eighteenth century. The exploitation of energy sources and the utilization of crude techniques from the pre-industrial ages through the first industrial revolution created a new monster which now threatens life as we know it (Vorley et al., 2015). The requirement of landfill and the unconventional methods used during exploration of fossil fuel (burning of coal), and iron among others, has left a big hole in the sky that future generations will only strive to maintain. Regardless, relentless efforts and technological interventions are cementing the path for a better and sustainable society.

2.2 Industry 2.0

The second industrial revolution era saw the use of electricity through a centralized distribution approach, first initiated in the USA, in the early twentieth century (1905). Electric power discovery offered more efficiency and performance for operation as an energy source and out-performed the old steam set-ups. Later in the nineteenth century, further development led to better designs of electrical devices, and over-time, portable energy efficient machines were developed, which led to increased productivity. Unlike the industry 1.0 era, the 2.0 featured organized manufacturing factories, equipment, and processes. The actualization of the assembly line automobile industry by Henry Ford ensued by the discovery of crude oil in Texas- USA also helped the Toyota company to initiate the first lean manufacturing concept to achieve cost-effective operation (Yin et al., 2018). However, during this time, electricity generation became inefficient due to reoccurring blackouts from power transmission capacity amidst substantial financial losses in operations. Most noticeable also, was the uncontrolled carbon discharge from the power plants and other industrial effluent causing damage to the ecosystem, which leads the US government to draw new plans for smart energy generation and tasked researchers to develop novel ideas and innovate future energy systems. Hence, it became a global pursuit, leading to the third industrial revolution.

2.2 Industry 3.0

Industry 3.0: The industrial revolution of the twenty-first century is gradually being phased out to make room for anew (I_4.0). Here, cutting-edge fast, smart and highly effective technologies ushered a systemic way to do business. Resilient ICT which includes extensive data management, superfast computers, mobile and electronic devices, among others have taken industrial productivity, economic and societal growth to a whole new level. The discovery, development, and implementation to use, new/renewable/alternative sources of energy sufficed in the third industrial revolution, leading to significant impact on the socio-economic and environmental bidding compared to the earlier, 1.0 & 2.0. More innovations continue to evolve within the Industrial 3.0 era, which cuts across, to unveil the current sustainability tactics in the transport and logistics sector (Tien, 2012). Efficient warehousing operations (solving the bottle-necks in inventory management), robust resources planning strategies, optimum material utilization, and product/equipment tracking systems are evidence of transformations from the past to the present as pertains manufacturing and services delivery. Noticeable in Figure 1, the complexity of the technology as well, productivity increased from subsequent industrial revolution to the next. However, because of the agitation for climate mitigation resulting from weather abnormality and environmental discomfort and through thorough research and development enhanced by innovative thinking, we now have sustainable concepts and smart system. An example is a smart grid, used as an optimized energy system, and which integrates the most advanced technology, combining latest information technology systems with high-performance hardware to generate energy with fewer wastes and less CO_2 discharge. In the world we live today, smart grid has already picked up in developed nations, promoting real-time prediction of the atmospheric condition and at the same time monitoring of general equipment performance as a deal breaker for power generation compared to technologies of the first and second industrial era when wireless sensors and IoT based technologies did not exist.

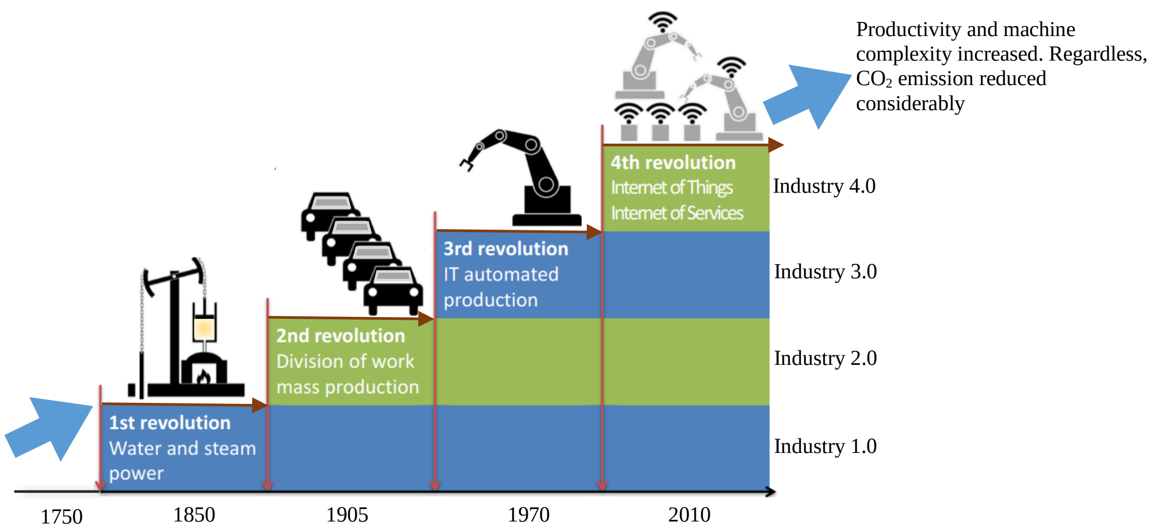

Figure 1. Technological Progress from the First to the Envisaged Fourth Industrial Revolution

Evolving technologies are facilitated through the use of the internet. IoT is logically the marriage between advanced communication technologies with sophisticated hardware for best performance. Energy management schemes of current dispensation depend mostly on the application of this concepts to create positive economic and social-environmental impacts (Jette, 2012). Energy storage systems (batteries, flywheel systems, and compressed air) are gaining predominance in meeting power demand requirements and replacing energy generation from variant sources. Apparently, because of the high-tech functionality which enables it to collect and process data of load demand data and inspire research. Solé's (Solé et al., 2018) argument concerning energy generation decline from fossil deposits (oil), directly focuses on the possibility to promote alternative technological intervention, through sustainable means and lead to a more sustainable financially stable economy. More importantly, Industry 3.0 features conservative techniques that now lay precedence for future development in energy utilization, energy efficiency management, and storage improvement, purposefully to reduce carbon emission, combat environmental degradation and mitigate the current climate anomaly. The subsequent section expatiates on future technologies for energy conservativeness and sustainable energy practices.

3. The Future and I_4.0

The ponder about what must have led to the birth of the idea of I_4.0 by the German group of scientists to optimize manufacturing in 2011, started from 1999, an idea which was finally penned on paper in 2009 by Kevin Ashton (Ashton, 2009). Like many other authors who have referred to the I_4.0 as the fourth industrial revolution, Gilchrist (Gilchrist, 2016) gives a definition, that is; it is the renascence of old concept through the use of newly developed technologies and approach that combines operational technology and ICT. I_4.0 incorporates innovative technologies like additive manufacturing, robotics, artificial intelligence and other cognitive technologies. Also, advanced materials, and augmented reality according to (Deloitte, 2015), cyber-physical production systems and IoT (Mittal et al., 2016). Fuchs (Fuchs, 2018) explains I_4.0 from the industrial point of view, to be a process where a product is manufactured through a wholly automated arrangement. The product, however, may be re-delivered for repairs, or recycled with no human assistance through the entire process of applying different commands and technological control via the Internet. The conceptualization of I_4.0 has quickly captured attention and the imagination for a fully automated manufacturing process as earlier conceived by the Germans has picked up speed on research towards it actualization to making engineering activities as convenient, efficient and more cost-effective as can be (Drath and Horch, 2014; Germany Federal Ministry of Education and Research, 2014). The ideology behind the I_4.0 backed by IoT is set to improve information flow, optimize controls, streamline automation and facilitate the man-to-man, and man-to-machine interface in the industry through a robust technological framework, under the new umbrella of Industrial Internet of Things (IIoT) (Gilchrist, 2016). Moreover, the deployment of the tech needed to achieve I_4.0 will require a little more time and careful planning to realize.

The high level of sensitivity involved and capability to handle complex roles envisage to deliver fully on the manufacturing of parts in engineering fields, operations execution for surgery in the medical area, real-time planning and monitoring of products through tracking and tracing for active logistics support, etcetera. As mentioned above, all stand as evidence to the diversification happening beyond the notion of I_4.0 as being solely for manufacturing and as such, are highly dependent on the application of Cyber-physical system, artificial intelligence and also, the ability to properly manipulate large data (Baheti and Gill, 2011). It is no wonder that investment interest on scientific research for some of the technologies mentioned has moved from the vision stage to a certain degree of actualization. In the current industrial dispensation more on innovation has created the possibility of crude oil exploitation to be carried out through a more sustainable approach, using drones to monitor site activities and satellite scans provide certainty of the results of mineral deposits, thus giving an assurance before incessant drilling leading to waste of land, water, mechanical input and overall energy. Hence, the application of the IIoT and the necessary technological drivers can create a sustainable working condition, and low risk to man, environment and conserve resources while so doing. Autonomous vehicles will now travel where a man may not reach and nano-sensors (implants) that can monitor health conditions in living organism, made possible through cloud computing. Least to mention smart farming, where a comprehensive detail of a well-organized farm is collected, processed and adequate decision made about necessary actions to be taken captures the level of robustness and applicability of IoT and things to come in the fourth industrial revolution era. IIoT technologies will control energy fluctuation and meet flexibility issues arising from consumption through optimization controls and sensor systems. Technologies like virtual power plants (Shabanzadeh et al., 2015), facilitated by IoT now makes it easy to monitor renewable energy integration and helps to eliminate the challenge of energy generation systems lack and energy-load assignment through cyber-physical energy system according to (Beier et al., 2018).

Smart grid energy system has become a cost saving attraction for manufacturing industries. Flexibility functionality may get to the height in operations of "generate what is needed." Non the less, companies are faced with the challenge of structural changes, and fitting of the new technologies, training, and staffing in the new area of technology selection (wind energy, solar, onshore, offshore, space and underwater). The requirement of an entirely new business strategic frame-work, cost-estimation of the automation process becomes a dilemma for future business managers to embrace a new model over the conventional. However, the capacity to answer the above question and solve these challenges presents the opportunity for growth and actualization of the I_4.0, which will lead to the realization of new economies, new lifestyle, and modern society. The $I_{4.}^{+}S$ will be driven by digitalization of all things and interconnectivity of operational process within a production flow line. E.g., in the manufacturing industry where adaptor technologies can anticipate human gestures and safely operate without obstruction, or real-time central autonomous control of HVAC systems for optimum performance through robust integration and connectivity of information.

3.1 Environment and Technology

The exploitation of the solid, liquid and gaseous potential of fossil fuels from the pre-industrial age to date have contributed directly and indirectly to the poor anthropogenic situation recorded today. The steady global increase in CO_2 emission shown in Figure 2 is, in no doubt highly captivating to both environmental protection and energy conservation players, as per the records from the year 1960 to 2014. Subsequently, the adverse effects of climate change and the need to mitigate its catastrophic implication has prompted proactive measure which has resulted in massive capital investments in renewable energy sources and utilization of efficient energy technologies. Figure 3 shows some countries listed for brief comparison that have invested hugely in renewable energy approach to tackle climate change in the past decades, with Germany, the United Kingdom, and Russian Federation registering a very sharp decline in CO_2 emission whereas other countries make efforts to remain within the bandwidth of low emissive discharge. These changes become significant in the early twentieth century and supposedly backed by innovation and sustainable thinking (Green initiative). However, with other wealthy nations whom, though have invested enormously in the green initiative (Figure 4), more still needs to be done, as emission trend looks to go higher, as the future is gradually shaped into a post-carbon society. Greenhouse gas emission must be plunged to the bare minimum (Kone and Buke, 2010), the most reason why the rise in the globes surface temperatures above 2˚C, tracked since the pre-industrial era should be managed (da Graça Carvalho et al., 2011), as decided at the 2015 Paris agreement on climate change.

The complexity of modern technologies requires careful attention, as it needs to be under control. More importantly, implementation and promotion of sustainable energy practices, through the use of appropriate techniques and approach must have necessary grounding and support. Sustainable energy practices according to this paper refers to energy efficient equipment designs, power sourcing from the renewable energy source and energy savings through conservative actions (optimization, replacement, and monitoring). Development of the technologies enabled by IIoT is designed potentially to be effective, flexible and to deliver high on quality. Hence, industrial operations where carcinogenic emissions and material waste are eminent is controlled to a reduced effect. The innovations in technology that carved the realization of the first industrial revolution; from steam-fired furnaces and engines, to iron mining/manufacturing to transport, all originate from fossils. Coal mineral opened a new door for sustained modern economic growth. The basic challenges, as observed by the first industrial revolution narrowed down to the nonconservative practices and poor combustion technology that existed in that era leading to very high carbon emission (Kone and Buke, 2010). Today, the various carbon capturing technologies which exists, now supports sustainable combustion while using coal, either for electricity or, in industrial manufacturing processes. Thus, limiting carbon dioxide emission/release into the atmosphere. Today, development of advanced technologies enabled by IoT and cloud computing makes it possible to monitor global CO_2 emission as countries are determined to reduce their emission contribution through the application of sustainable energy practices, such as Germany, Russia, and The United Kingdom etcetera (Figure 3).

Global energy consumption will rise invariably as the population growth rate increases. The industrial energy efficiency, defined as per GDP use of energy improved in the previous years in different developing countries than in developed countries. However, with regards to the few of the developed nations which have championed technological integration into energy management systems (figure 3) tends to register a decline on their scorecard for carbon emission. An example in China's economy improved by a rise of up to 6.9% of their GDP through improvement of their energy intensity (Energy Intensity can be expressed as the ratio of the gross inland consumption of energy to the total domestic profit or GDP, obtained for any year in-time). Technologies which help to facilitate industrial optimization and operational processes, through the reduction in energy losses (transmission, distribution, and billing, etc.), swap from nonsustainable energy practices (including the use of carbonaceous Thermal Power Plant) and renewable energy technology deployment, having to become the new synergy to industrial energy maximization and environmentally harmful emission reduction.

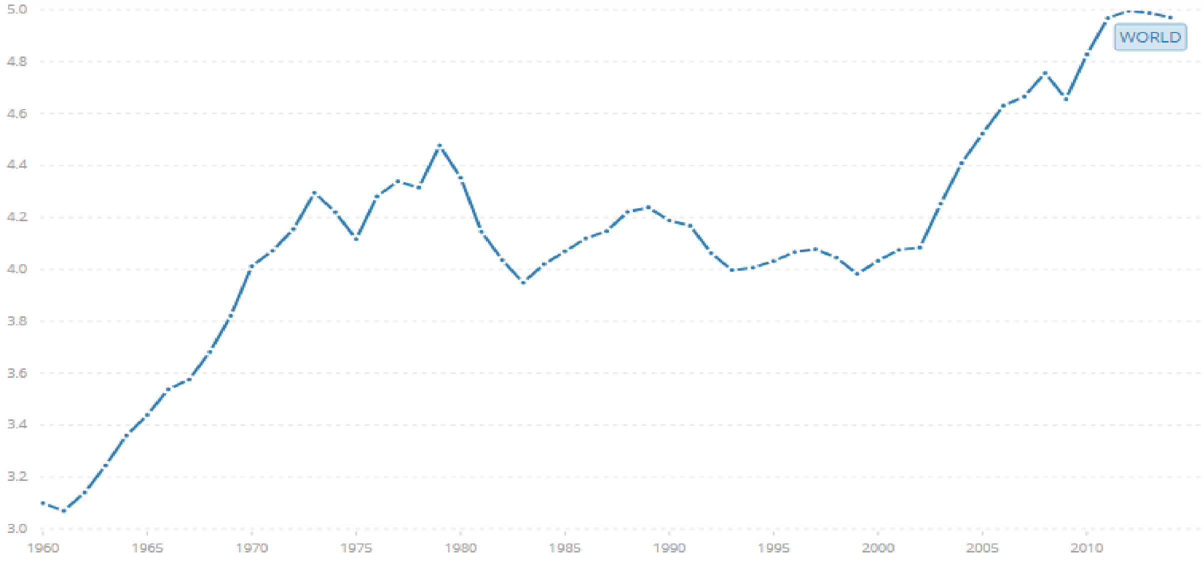

Figure 2. Showing global carbon dioxide emission (per metric ton, per capita) from1960 to 2014. Data Source: (“data.worldbank.org,” 2018)

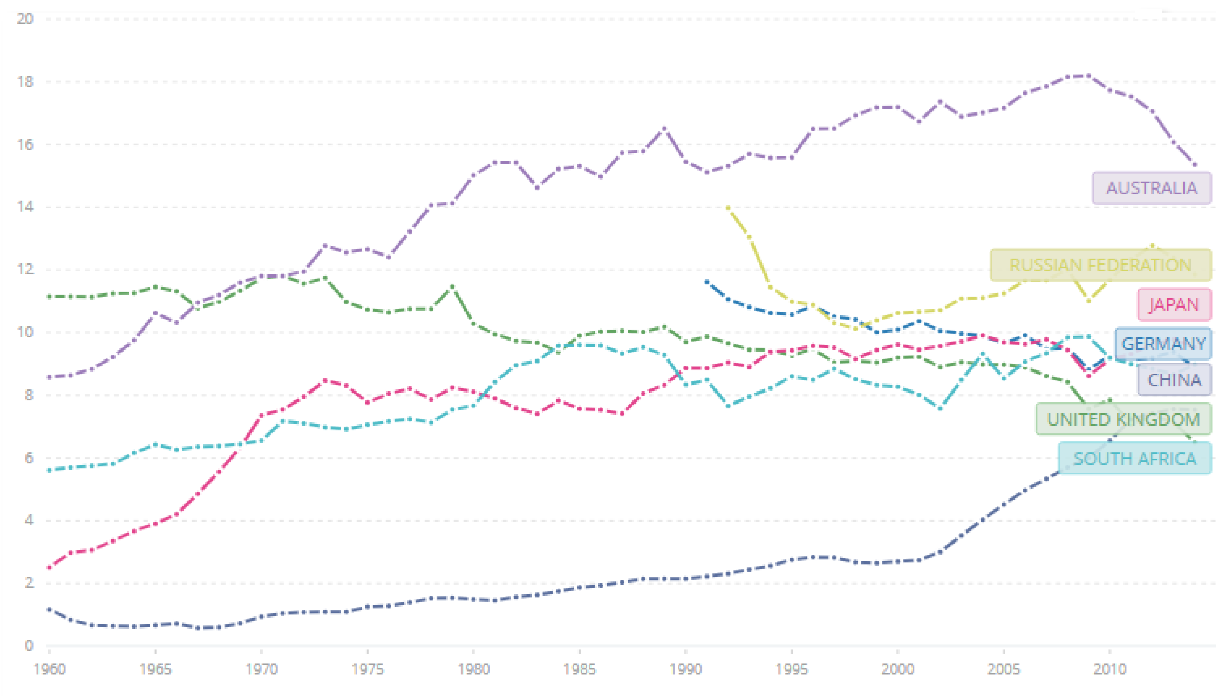

Figure 3. Showing carbon emission (per metric ton, per capita) from1960 to 2014. Data source: (“data.worldbank.org,” 2018) (For selected countries considered developed, have invested hugely in sustainable energy implementation, and actively supports the prospective future of $I_4.0$ to drive their economy to be possible).

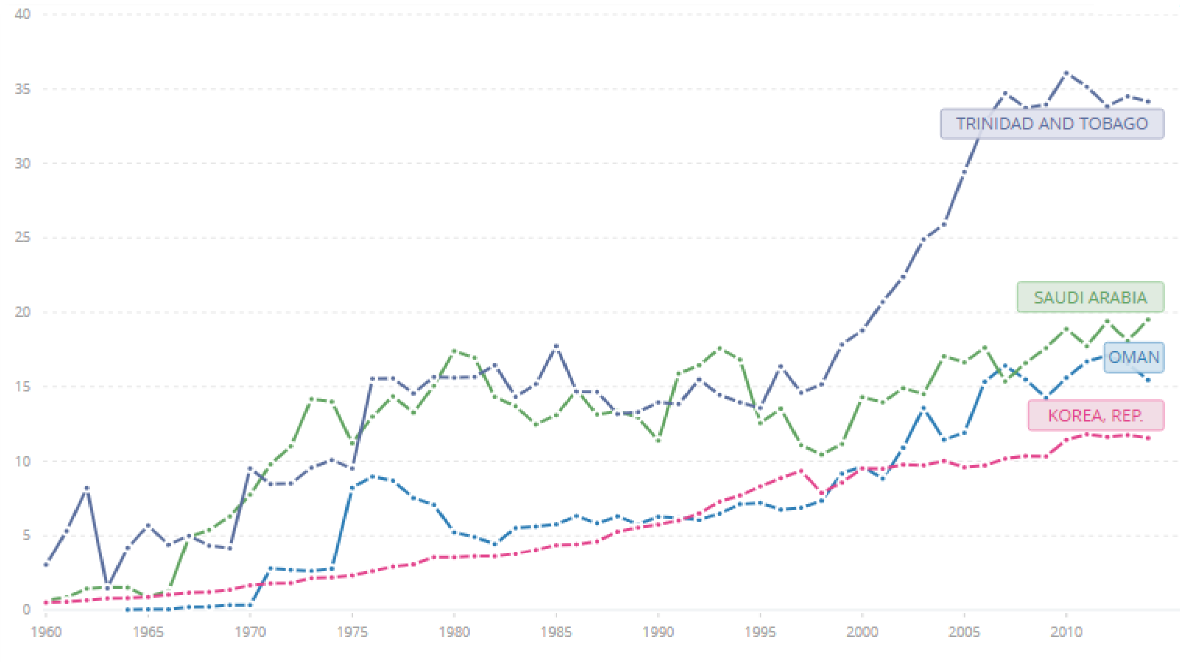

Figure 4. Showing carbon emission (per metric ton, per capita) from 1960 to 2014. Data source: (“data.worldbank.org,” 2018) (For selected countries considered rich in oil activity and very high CO_2 level, may or may not have implemented the green initiative, may or may not support the concept about $I_4.0$).

4. Discussions and Conclusion

The attainment of optimum energy efficiency and CO_2 emission reduction with regards to the implication of actualizing industry 4.0, depends on the capability of the aligning technologies (IoT, Cyber-Physical Systems, etc.) As such, when incorporated into energy management, enhance energy security, ameliorate fuel scarcity and generate beneficial jobs while still promoting competitiveness amongst SMEs’ and conglomerates alike, who are involved in the energy market. The I_4^+S which in this paper refers to the stage after successful actualization, and demonstration of the $I_4.0$ through all the technologies responsible for unveiling its maximum potential and landing, on a digital society. The practical application of the framework to ensure smooth implementation on smart factories, energy, building, transport, services (health, sales, delivery, payment) and intelligent monitoring of the environment, will usher new economies with new business players and tremendous potentials. The development of unique transport systems, such as service companies like Uber and other online hosts business platforms like Amazon and Alibaba to mention a few is the beginning of what is yet to come in the future of transport and customer service delivery which utilizes IoT. The correlations of energy resources and technologies with current practices, operational competence and the way it is being managed or how the result affects the economic cost of living, energy production, consumption, and utilization are based on the zeal and commitment to move from ideation to fruition. The envisaged future intervention will replace traditional means of cooking and heating, from the domestic point of view, through using biomass and other crude methods. The I_4^+S will feature in its entirety, smart buildings, with conservative energy plans (generation, consumption, and savings), smart factories, smart services, smart energy sourcing, smart transport, and smart farming to mention a few which in every step integrates sustainable technology that replaces the primitive technique and improves wellbeing.

Although arguably that IoT will increase productivity, as well as lower costs through the extensive use of smart mechanical technology. Regardless, IoT has its concerns, which may well act as a dire hindrance to its adoption. Skills accusation will drastically reduce. As such, there will be a decline in the standard of leaving as a high number of menial laborers may be phased out upon the full implementation of the fourth industrial revolution, leaving consumers oppressed and frustrated not being able to survive the new system. Hence, the promulgation of $I_4.0$ and possibly the transition to $I_{4.}^{+}S$ threatens to leave a society where massive unemployment becomes imminent. The application of service robots, the operation of automated factories, and internet market networking, will in all sense necessitate the review of employment policies and regulations concerning job quotas. Information dissemination and the training of everybody about everything new will become the new interest for government in other to maintain social security. Thus, provide the society with the knowledge of how to live and appreciate the modern industrial era. As such, promote fair competition and further innovative thinking for the latest resolve.

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