Antecedents or Digressions?: The Socio-Economic Impacts of Renewable Energy

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Abstract--**The global energy future: availability of energy supplies, energy security, environmental sustainability and strength of energy demand, amidst competitive market forces and global economic crisis, is underpinned with aggressive visions of cost-effective technology management, strategic business portfolio, and integrated climate policies. However, the undisputed potential of renewable energy, emphasized its emergence and role in the diverse portfolio of global energy mix. Therefore, as part of the central theme to affordable clean energy, this paper (1) reviewed the developments of renewables compared to natural gas, (2) analyzed the momentums in large-scale renewable energy technologies driven toward global economy, and (3) evaluated the socio-economic motives of the transition toward low-carbon futures along with climate change issues. The indices of capacity growths in renewable energy sector are crucial toward the achievement of energy sustainability.**

I. THE NATURAL GAS AND RENEWABLE ENERGY DEMANDS: THE GLOBAL PERSPECTIVE

Global needs for energy—driven by energy prices, technological innovations, economic growths and demographic patterns—have increasingly been on the upward trend. Today, over 80% of the world total primary energy supply (TPES) is guaranteed by fossil resources—oil, coal and natural gas (see Figure 1). However, due to uncertainties since 2009 on the global energy landscape: The economic downturns, challenges of climate policies, and complex-constraints of environmental footprints, have slowed the global natural gas demands [1], [2]. Current trend in gas demand in 2013 increased by just 0.8%, compared with 1.8% in both 2011 and 2012. Explicitly, in 2014 global gas production reached a record high of 3,524 billion cubic meters (bcm), and the demand is projected to 5.4 trillion cubic meters (tcm) in 2040. Globally, the statistics of huge proven gas reserve at about 187 trillion cubic meters (tcm), at the end of 2014, gave reasons for resumption of upward trajectory of demand, and for optimistic low-carbon future. Even more, the long-term global recoverable gas resources have reached more than 850 tcm, with unconventional gas resources—mainly coal bed methane (CBM), 'tight gas' and shale gas—accounting for 60% of global gas production. Yet, the recent marginal global gas demands have declined, to the extent that re-evaluation in strategic cost leadership of natural gas as the central theme in affordable clean energy is warranted. For instance, gas-fired generation dropped sharply in 2013 both in Europe and U.S., while global liquefaction capacity held at almost 400 bcm with an additional 150 bcm under construction. The shale gas exploration is also on a decline in reference to the 2020 target—from 100 bcm to 30 bcm [3].

Hence, the driven profitability in the global energy mix, to attain energy efficiency and security, are re-emerging on the energy landscape. To that end, the emergence of renewable technology has added new frontiers to waves of innovation and research, aimed to develop crucial variable renewables and second-generation biofuels [4], [5]. The second-generation biofuels are derived from lignocellulosic resources—including forest-based plants, non-feedstocks such as jatropha seed, switchgrass, and miscanthus—which are structural materials composed mainly of cellulose, hemicellulose, and lignin. These are processed into cellulose ethanol, biodiesel, flexible fuels, and other transportation fuel blends—E10, E25, and E85. Further, a huge extension of non-plant feedstocks: lipids, microorganisms (micro-algae, bacteria, and yeasts), and animal products, have been on the mainstream of process technologies of biomass-to-liquids conversions at commercial scale [6]. Renewable energies—including hydropower, solar, wind, geothermal and biofuels—with prospects of security, reliability and sustainability in low-carbon energy, are in critical need of energy investments and policy alignment [7]-[9]. Notably, renewables are major sources of new power generation, with 80% generation in Organization for Economic Co-operation and Development (OECD) countries, 35 % in non-OECD, and China accounted for 40 % (310 GW) of the global growth. While most of the increase, in absolute terms, are in renewable-based generations, however, competitiveness in cost with fossil fuels and other energy sources is central. Significantly, global renewable electricity production was projected from about 4500 tetrawatt hours (TWh) in 2005 to nearly 6000 TWh in 2018, approximately 25% increase; that is, 45% increase between 2013 and 2020 to reach 7310 TWh. On this trend, it is expected to exceed natural gas by 2016 (see Figure 2). Worldwide, renewable power annual capacity addition is forecasted to over 120 GW in year 2020. Biofuels as part of renewable energies would account for 4% of road transport fuel demand in 2020 in 2°C Scenario (2DS) propounded by International Energy Agency (IEA)[10,][11]. The 2°C Scenario is an interim 2020 targets in Energy Technology Perspective (ETP) in absolute generation and investment levels. Though, the investment in renewables peaked in 2011 to nearly $300 billion, it declined shortly after, to steady off at $250 billion in 2013[12]. The slow capacity growth and fall in technology costs were attributed to technology and emission policies. Moreover, the expected challenges: mature markets that introduces low or negative energy demand, to unpredictable policy framework which slowly adapts to technology cost changes, and barriers of deployment have not detracted renewable electricity in clean energy scenarios—though not without growing concerns.

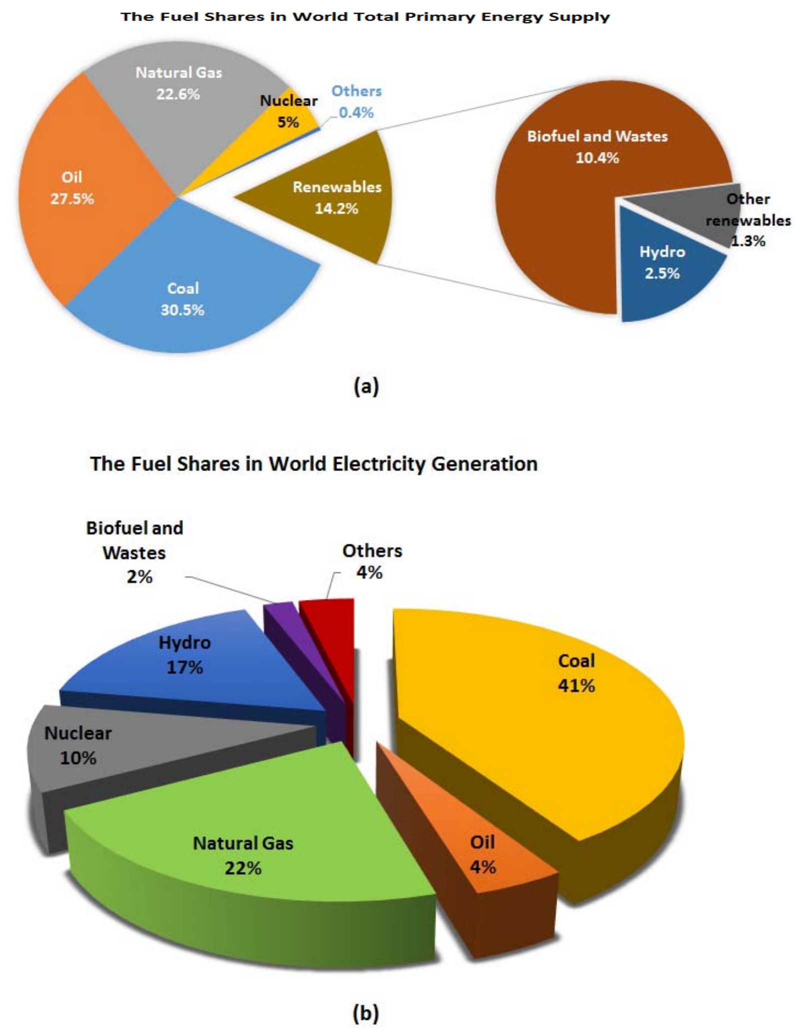


Fig. 1: Trends in (a) the Fuel Shares of World Total Primary Energy Supply (TPES) in 2013, (b) the World Electricity Generation in 2013 by Fuel Shares (Source: IEA Energy Statistics, 2014).

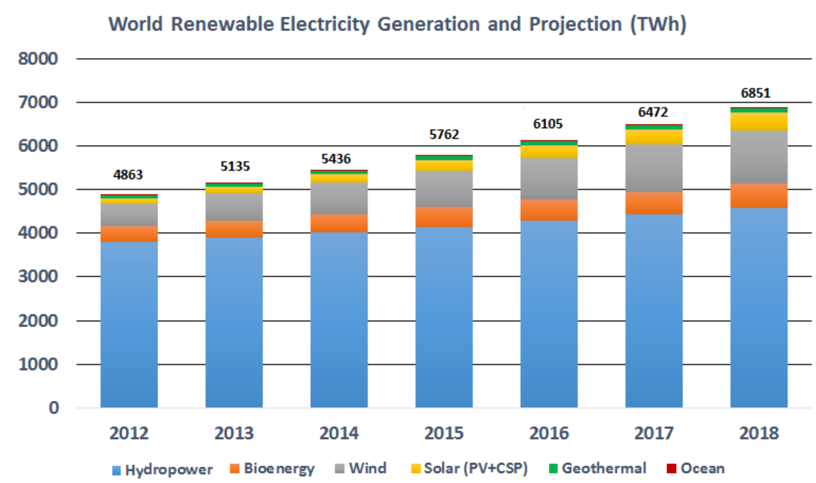
II. FUELLING THE FUTURE: THE LIQUEFIED NATURAL GAS (LNG) BUSINESS MODEL AND STRATEGIC COST LEADERSHIP

Reshaping the future of natural gas demand on the global energy scene, along the gas value chain: refining, supply, transport, distribution and marketing of natural gas, including power generation and sales strategy, to maximize business models and establish leadership role through business execution strategies, poses several challenges. This is because weak industry fundamentals persist—surge in excess capacity, reserve depletion, economic crisis and boom in unconventional gas resources. These factors culminate in weak demand and inability to absorb existing supplies. Against the backdrop of this gloomy outlook, diversification of gas supplies, improvements in corporate performances, and collaborations—through partnerships and synergies—must be ensured for gas market stability, sustainability, and competitiveness. The total LNG imports in 2014 amounted to over 300 bcm compared to about 200 bcm by pipeline. Further, the global electricity production by natural gas in 2013 fuel shares was 21%. Within the OECD countries in 2014, natural gas imports by pipeline waned by an average of 14.4% for European Union (EU) members, while in U.S. alone it increased by 39.6% due to seasons. This represented the first clear price disparity since 2007: The European market at $9.54/million British thermal units (MBtu) compared to $5.11/MBtu in the American market [13]. Currently, the global LNG business model shows similar price characteristics. In addition, regulatory frameworks, evolution of low-carbon technologies [Liquefied natural gas (LNG[1]) and Gas-to-Liquids (GTLs)], arbitrage investments, and ongoing patterns of growths in China and India are unprecedented factors in the gas portfolio, which need thorough re-appraisals to achieve the long-term forecasts.

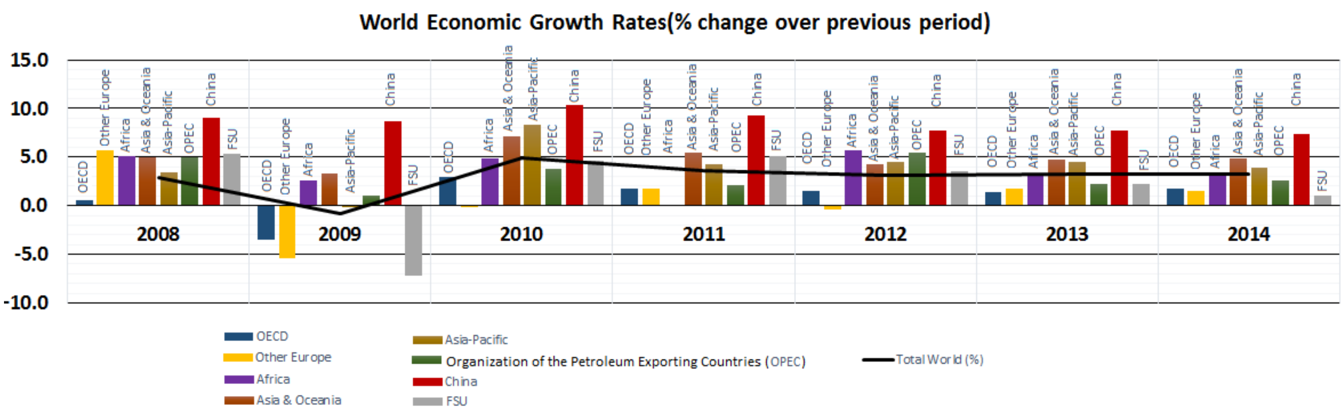
[1] The cooling of natural gas, through successive cycles of refrigeration using compressors and heat exchangers, at −162°C to produce non-toxic liquid—for LNG shipping—is behind the LNG technology.

Figure 3 summarizes the trends in world natural gas production and consumption. In year 2014, the variation in LNG import in Asia alone was nearly 3.5 bcm at about $7/MBtu above prices in Europe, reflecting greater gas usage. Of course, the LNG chains—liquefaction, shipping and regasification—substantively, have contributed toward availability of natural gas, with apparent competitive edge from equity production. Indeed, the idyllic scene of liberal energy market—in which customers are free to choose the supplier of gas according to needs, quality of service and price offers—must withhold depressive pressures on gas demands to drive up capacity utilization.

Meanwhile, unconventional gas reserves, which required a range of special drilling and stimulation techniques due to low permeability in rock formations are estimated at over 900 tcm. These were global ‘resource plays’ of recoverable reserves of ‘tight gas’ sands (200 tcm), CBM (250 tcm) and shale gas (450 tcm)—with 25% in the United States and Canada alone, beginning 2008[14]. Accordingly, accelerated production rates, domestic consumptions of unconventional gas, combined with global weak gas demand have led to steep falls in market prices, marginal production cost, and LNG importation cuts in the U.S.. Whether these price affordability scenarios could be replicated with China, Iran, and Russia—with potential prospects of non-conventional gas production—remain debatable. However, technical barriers of extraction, proximity to market, and production declines, are persistent problems in need of immediate solutions. Despite these difficulties, advances in technology innovations—3D assessment of reservoir characteristics and state-of-the-art combine cycle gas turbines (CGGTs)—are leverages in gas-fired power generation and unconventional gas market. Consequently, to sustain momentums and growths in the natural gas market: enhanced operating performance, cost efficiency, and strategic portfolio quality along integrated value chains are vital factors for shifts from a recondite energy outlook, to a sustainable, lower-carbon economy and beyond.



(a)



(b)

Fig. 2: (a) The World Electricity Generation in 2013 by sources, (b) the World Economic Growth Rates in 2013 (Source: IEA Energy Statistics (2014) and OPEC).

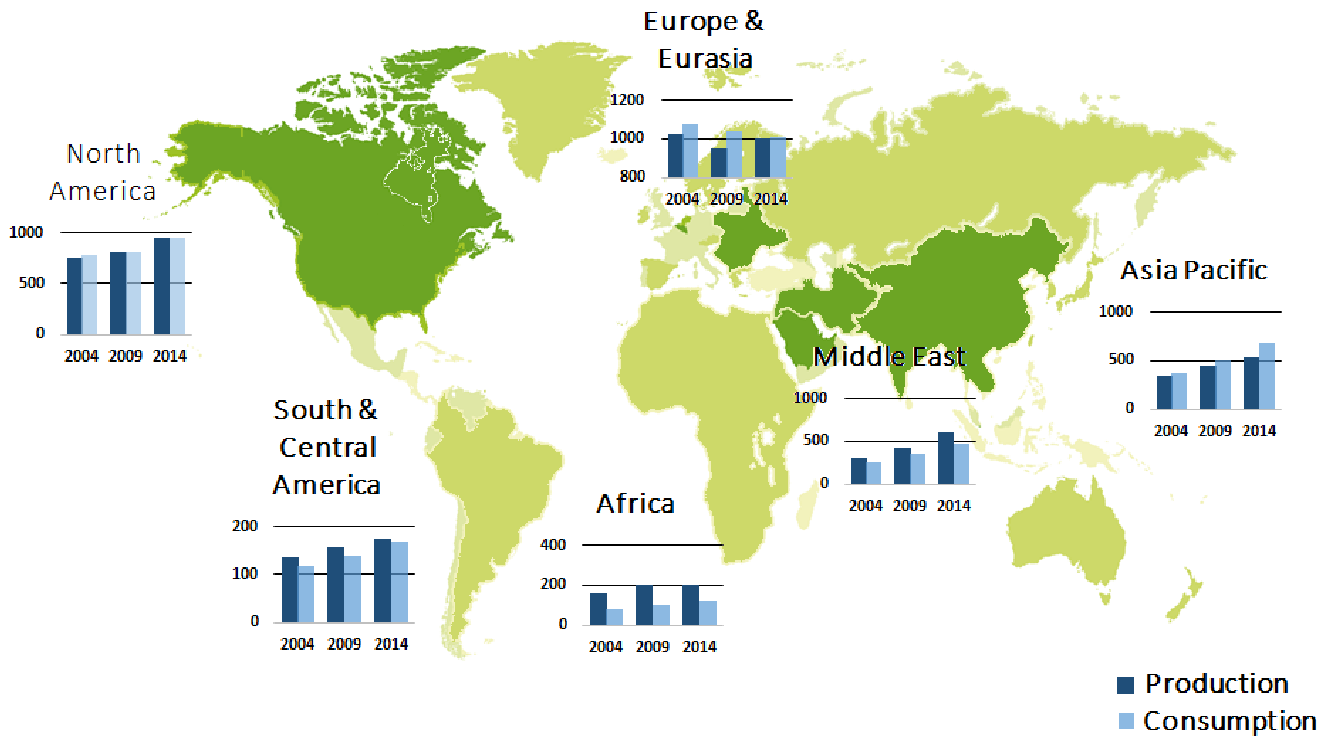


Fig.3: Trends of Global Natural Gas Production and Consumption (units in bcm)

III. RENEWABLE TECHNOLOGIES AND CLIMATE CHANGE POLICIES: THE APPROACH TO SUSTAINABLE LOW-CARBON FUTURE?

Consider the facts: Clearly, the old energy infrastructure is inadequate—challenges of climate and investment inertia—while the proposed new models remains abstruse. Shortfalls in fuel types have undermined the sustainability of economic growth; indirectly weaker fossil-fuel prices have discouraged investments in clean energy technologies responsible for long-term availability of energy supplies, security, environmental sustainability, and economic development. To alter the present energy landscape, viable and scalable optimized business outlook of diverse energy mix are required—for lower emission paths. Furthermore, the energy market and dynamic interactions of driven forces require the understanding of market fundamentals—energy market regulations vis-à-vis policy constraints. These include the optimization of subsystem structures of integrated fuel value chains (FVC) and absorption of perturbations from potential game changers. Thus, the earlier quasi-steady state of renewable energy sectors have obtained market stability—with industrial investments in technology, and lower-carbon technological breakthroughs, as heuristic transients in curbing emissions. The feedbacks, in the quest for a competitive energy future, have been maximized by international research collaborations and deployments of low-carbon technologies. In 2012, 40% of the global electricity generation was by coal-fired generation. The consumption of coal by China only in year 2013 was over 50% of the world coal resources. The trends in CO_2 annual growth have dictated the reductions of the carbon intensity in energy consumption unachievable—a potential threat to climate policy targets and future energy revolution. Unless a requisite of indispensable technologies (energy conservation technologies) progressively penetrate the market to ease the pressures on CO_2 emission mitigation strategies, the global energy security would fail. And, renewable energy technologies that offer lower-carbon alternatives are poised to meet the challenges. As part of global energy diversification, renewable-energy subsidies grew from $39 billion in 2007 to $66 billion in 2010, aligned with rising production of biofuels and electricity from renewable sources. In 2013, global subsidies to renewable reached $121 billion, a 15% increase on year 2012 and is expected to expand to $230 billion by 2030. While the European Union (EU) remains the main advocate of renewable energy, over 75 countries are projected with onshore wind capacities greater than 100MW by 2018; solar photovoltaic (PV) cells at 100MW levels are expected in 65 countries, while bioenergy at the same level would be realized in 50 countries by 2018[15]. Figure 4 shows the projections of world renewable generation by electricity to year 2018.

Further, global deployments of solar energy technologies include: Photovoltaic (PV) cell, concentrating solar power (CSP) or solar thermal, to harness the abundant energy from the sun. The PV cell technologies vary from multi-crystalline silicon (×Si), CIS thin film materials (Copper Indium Di-

Selenide), and dye-sensitized cells [16], to organic (polymer-fullerene) cells, and ETA cells (Extremely Thin Absorber)], currently used in space applications [17], [18]. Though wind power generation produces less than 5% of the global electricity, it is carbon-free and increasingly cost-effective [19]. Roscoe Wind farm, currently implemented in Texas, U.S. at total installed capacity of 781.5 MW is the world's largest (627-turbine array), which covers about 400 km^2. The Horse Hollow Energy Center at 735.5MW is the second largest array with 291 turbines (manufactured by General Electric, Mitsubishi, and Siemens), over 190 km^2 of land. In addition, Whitelee Wind Farm in Glasgow, Scotland at 322 MW capacity, is online for future expansion to almost 600MW as Europe's largest—an array of 140 wind turbines at a project cost of €350 million. Offshore, Thanet Wind Farm in United Kingdom (UK), as of September 2010, was the biggest wind farm with nameplate capacity of 300MW which covers 35 km^2 area, at over $1.2 billion—adequate to supply approximately 240,000 homes. Under construction, the largest wind farm developed with proposed 320 turbines consisting of 1.5 and 3MW generators, over 36km^2 area, to produce 800MW power is Alta Wind Energy Center, California, U.S., capable of 52Mt of CO_2 emission reduction. By 2020, the largest proposed wind farm project, the Gansu Wind Farm at 20,000 MW in China would be developed at an estimated cost of $17.5 billion; installed at capacity of 5160 MW, as of November 2010. Why these developments may be of particular interests, side comments as to the environmental impact assessments (EIA) cannot be completely ignored. Apart from aesthetic impact on location and high mortality rate of migrating birds and bats, turbine noise seem to be the only environmental effect observed so far. These seem negligible, or could be dismissed when compared to other human activities which critically endangered species [20]-[25].

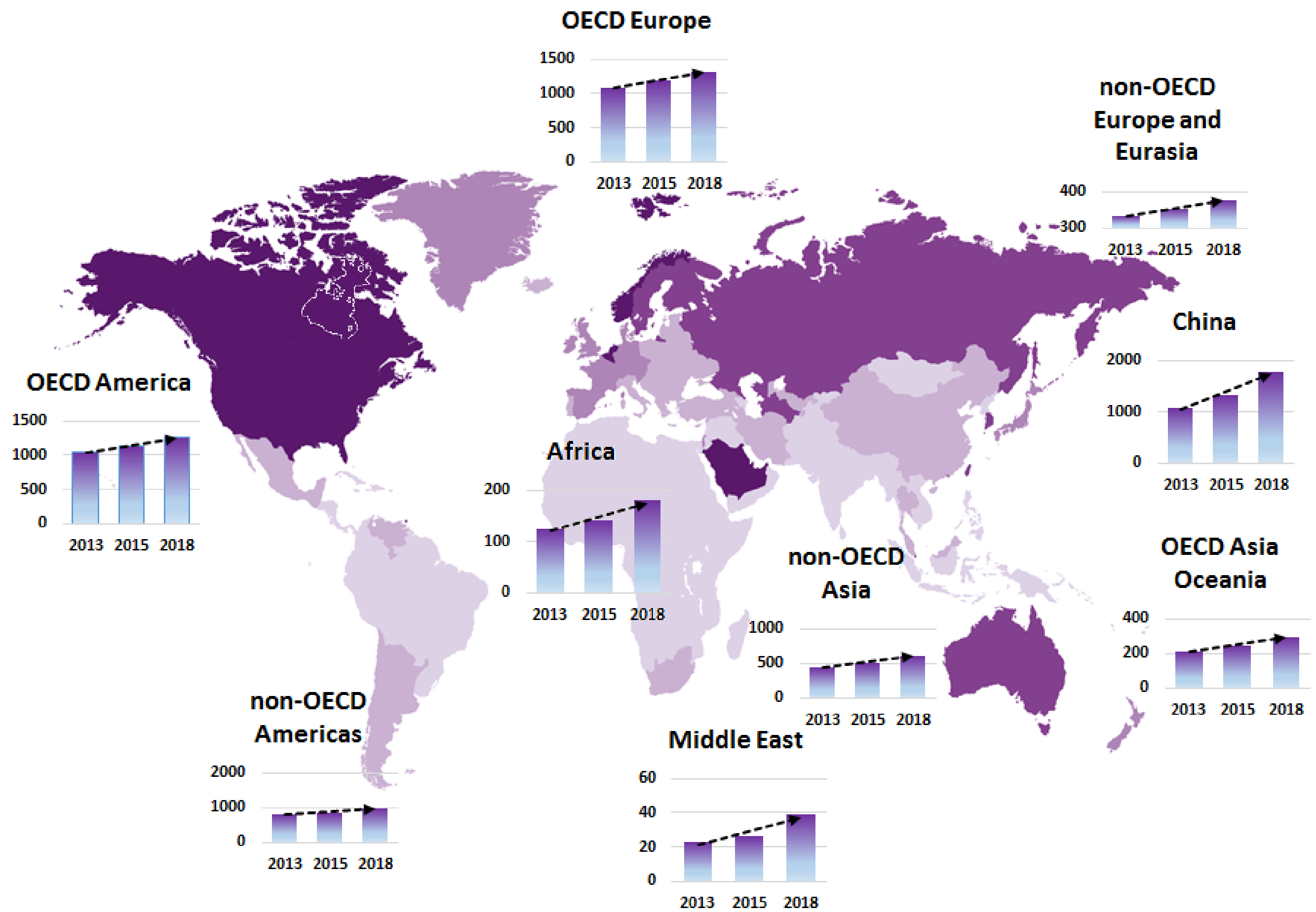


Fig.4: The Global Renewable Energy Generation by Electricity (units in TWh).

Unquestionably, biofuel would be a major driver in future energy revolution, especially in the transportation sector. To that end, biorefineries—facilities which integrate complex biomass conversion processes and equipment to produce fuels, power and chemicals—use genetically modified feed (GM) fuel crops to improve the efficiency of existing bio-conversion systems and boost biodiesel or fatty acid methyl esters (FAME), biogasoline production. Understandably, based on existing energy time-series and technology conversions (enzyme production, enzymatic hydrolysis, and ethanol fermentation), the future trends in biofuels production are now integrations of collaborative efforts toward greenhouse gas (GHG) emission-reductions and clean energy—at affordable prices. This is because glimpses of global energy perspectives, on the horizon of secured, sustainable and efficient energy projections, reveal momentums in biofuels than in other renewables. At the end of 2010, world biofuels production increased as much as 13.8%, accounting for 0.5% of global primary energy consumption. The growth was attributed to North America, South and Central America regions with +17.7% and +14.2% respectively; about 75% of global biofuels production. In 2012, global biofuel production was on trajectory of 0.5 million barrels per day (mb/d) to reach 2.36 mb/d in 2018. In year 2013, biofuel had 10.4% of the total renewable energy (1,829 million tonnes of oil equivalent (Mtoe)) in the world total primary energy supply (TPES) estimated at 13,555 Mtoe. Though ethanol dominantly accounts for some 75% of world biofuels production, with North America, and South and Central America as leading producers, the economic challenges of blending more than 10% ethanol in the gasoline pool raises concerns, along with high feedstock prices[26],[27].

Undeniably, large-scale investment in renewable energy mix is much needed. Beside cost-effective reduction in gasoline consumption, economic impacts, and environmental advantages, the substantial decline in greenhouse gases (GHGs) suggests biofuels as sustainable substitutes to conventional gasoline and diesel—on ''well-to-wheel'' CO_2 basis [28]. However, criticisms as to financial burdens imposed on potential consumers of biofuel and community funds, alluded to an economically inefficient way of mitigating global emissions [29]. Not to mention the social fears attached to the bio-energy products as alterations of natural processes. Notably, though, Iogen Energy, Codexis, Virent, Verenium, and Martek Biosciences are veritable pioneers in joint technology development programmes designed to produce ethanol from agricultural residues using enzymes; evolve natural enzymes to improved variant enzymes ('super enzymes') for biomass to fuel conversion; and convert plant sugars directly to high performance liquid transport fuels. Future expansions, commercialization of cellulosic ethanol, and production of cost-effective microbial biodiesel through fermentation, are programmes at demonstration stages. Although, the benefits of energy production—in socially, economically and environmentally responsible pathways— far outweigh the costs, nevertheless, the debates whether societies would succumb to the rigors of research, development, demonstration and deployment (RDD&D) of biotechnological solutions are far from over [30].

IV. NATURAL GAS, RENEWABLES AND 'GREEN ENERGY ECONOMY': THE TECHNOLOGY EVOLUTIONS AND THE CARBON FOOTPRINTS

Odd twists in the global economy have witnessed, noticeably, migrations from regional market to globalization of natural gas market—the results of integration of LNG trade patterns and pipeline expansions across regions. Arguably, few hold tenaciously to the view that gas would always remain a regional fuel—amidst geopolitical issues, differences in resource endowment, alternative energy sources, and rising concerns of long-term versus take-or-pay transactions. Yet, one fact remains: Inter-regional gas trades and LNG importation dependence have created flexibility in trades, increased market portfolio, making gas well-positioned to be a freely traded commodity. For many countries, emergence of major oil and gas companies heralds an era of economic opportunity: National and international gas productions are prospects for skilled individuals in offshore platforms, processing facilities, pipelines infrastructures and, of course, in generation of significant revenues. Exploration and development in the North Sea, Alaska, Gulf of Mexico (GoM), Azerbaijan, Middle East, and Caspian regions—to mention a few—are instances of successful developments and integration of advanced technologies to sustain and, perhaps, increase the global proved gas reserve—which equaled 60 years of current production.

Today, the world clamors for well-functioning energy market to provide reliable, affordable and efficient natural gas supplies. What is more, technology evolutions in liquefaction and regasification (gas-to-liquids technology to deliver synthetic gas (syngas) and distillates to market); the new drilling technologies (multi-dimensional drilling for developments of sub-sea production facilities); and seismic imaging techniques (3D and 4D surveys to detect and reveal the existence of oil and gas reservoirs), are repertoire of innovations underpinning the leading role of gas toward that objective. In addition, controlled source electromagnetic (CSEM) measurements to confirm oil and gas resources; corrosion-resistant super-alloys as chemical barriers between oil and water; and combined cycle gas-fired turbines (CCGT) for power generation are new frontier of developments to sustain production. Moreover, the deployment of carbon capture and storage (CCS) to capture CO_2 and store underground for enhanced oil recovery (EOR) via satellites imagery are targeted toward minimization of GHGs [31]. Overwhelmingly, then, the reasons for a 'green energy economy' (or near-zero emission economy) [32], [33] cannot be disregarded. In 2009, the ratified Kyoto Protocol [23] and the Copenhagen Accord in the 15th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) set a non-binding intention of limiting the global incremental temperature to 2°C above pre-industrial level in 2009 [34], [35]. In 2012, Rio+20 UN Conference on Sustainable Development in Brazil brought together governments, international institutions and major groups to agree on decisive measures on clean energy and a more sustainable and fair use of resources. By December 2015, the 21st conference of the parties (COP21) in Paris, would reaffirm the decarburization pledges from various countries toward the achievement of 2°C scenario (2DS) relative to pre-industrial levels—main attention rests on China and U.S. [36], [37]. Obviously, diversification in gas supplies plays a pivotal role in these transitions to lower-carbon options for future economic growth. However, implementation requires extra investments—$100 billion p.a. by 2020—for climate mitigation and adaptation in developing countries, but with numerous co-benefits. Needless to say, untold environmental footprints in the wake of gas flaring, inefficient petrochemical plants, and associated exploration and production (E&P) activities necessitate deployment of strategic, optimized business models by various energy companies—for policy sustainability.

Careful consideration, also, must be given to end-use of renewable technologies: Energy storage, advanced fuel cells (alkaline electrolysers), hybrid and battery electric vehicles (HEVs and BEVs). Energy efficiency prospects through vehicle hybridization—plug-in hybrid electric vehicle (PHEVs), electric vehicles (EVs), and fuel-cell vehicles along with biofuels, as means to cutting fuel use and achieving reduction in transport emissions have increasingly become viable. The global sales of EVs grew about 50% between 2012 and 2013. Similarly, sales of PHEVs and BEVs increased by 57% and 43% respectively, within the same period [38]-[43]. These have led to improvements in internal combustion engine (ICE), a suitable panacea to increased concerns over the environmental impact of petroleum-based transportation infrastructure. Further, large-scale energy storage capacity was over 145 GW in 2014, about 97% of which was hydro-pumped. Owing to a strong shift toward electricity and hydrogen fuels, decline in light-duty ICE vehicles may occur by 2030 [44]-[46]. Cumulatively, the use of biofuels in an upward path might rapidly replace distillates fuels—for trucks, ships and aviation by 2050. In year 2020, 200 billion liters of biofuels are projected for transport fuel replacing gasoline and diesel. In the foreseeable future, barriers such as lack of awareness by consumers, huge initial costs of technology adoption, and low priority incentives placed on energy efficiency are detectable. Surely, the entwined energy technology revolution from natural gas and renewables require, clearly defined government policy actions, technology management, and adaptive end-users, to successfully put the world on sustainable energy path.

V. THE LOWER-CARBON ENERGY REVOLUTION: RENEWABLES OR GAS?

The fundamental objectives of future low-carbon energy—on the bastions of enhanced corporate responsibility and greater transparency—advocate efficiency, competition and liberalization in renewables and natural gas market, with basis on leading market reforms. Diversification of gas supplies promote free and open energy market. Further, initiatives in alternative energy supply—biofuels, solar and wind power—should be promoted, to ensure future growth in low-carbon options in businesses. In addition, subsidies should not be funded by increased taxation of other forms of energy. Put simply, energy efficiency is essential for future economic growth, still carbon pricing must be broad-based and implemented with prudence for realization of goals—with unnecessary damage on the global economy. Finally, energy policies which fail to encourage significant investment in natural gas production and renewables forebode ills. Guided by these principles of consolidation, global synergies, alliances and collaborations in RDD&D at various scientific disciplines to address contractual problems peculiar to energy industries, hold the key to the future of low-carbon energy [47]-[52]. Higher technological commitments worldwide, between the energy sector and academia, renowned universities, national laboratories, and research institute, should be intensified. This should be by ways of investments in research programs focused on climate change and emission reduction, awards for cutting edge research in new frontiers of hydrocarbons and non-conventional sources, environmental remediation, and management of intellectual properties. Of course, competitiveness on the dimensions of operational performances, deployment of emerging low-carbon fuels and power are emphasized. However, the LNG import-export ventures and renewables would continue to be key players in clean energy production—especially for growing markets around the Mediterranean, Europe and the Middle East. Even so, as the myths and facts of recent financial crises unfold, and the gas market remains optimistic of imminent recovery, even as the efficiency impacts of renewable energy accelerate to global scale, the trajectory of the technological revolutions toward the successful transition to lower-carbon energy exists beyond present innovations.

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APPENDIX A

TABLE A1. SUMMARY OF THE WORLD RENEWABLE GENERATION AND PROJECTION (TWH)

World Renewable Generation and Projection in TWh							
Energy Sources	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Hydropower	3792	3888	4010	4136	4276	4423	4570
Bioenergy	373	396	428	463	498	530	560
Wind	519	626	725	840	952	1080	1220
Solar (PV+CSP)	106	147	192	239	289	344	402
Geothermal	72	77	80	83	88	93	97
Ocean	1	1	1	1	2	2	2
World Total (TWh)	**4863**	**5135**	**5436**	**5762**	**6105**	**6472**	**6851**

(*Source: WEO 2011-2014*)

APPENDIX B

TABLE B1. SUMMARY OF THE WORLD ECONOMIC GROWTH RATES BETWEEN 2004-2014

World Economic Growth Rates (% change over previous period)											
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
OECD	3.3	2.6	3.1	2.6	0.6	-3.5	3	1.7	1.5	1.4	1.8
Other Europe	6.6	4.8	6.5	6.2	5.7	-5.4	-0.1	1.7	-0.4	1.8	1.5
Africa	5.1	5.4	5.7	6.2	5.1	2.6	4.9	0.1	5.7	3.2	3.3
Asia & Oceania	6.7	7.1	7.2	6.9	5.0	3.3	7.1	5.4	4.3	4.7	4.9
Asia-Pacific	6.0	5.2	5.5	6.2	3.4	-0.1	8.3	4.3	4.5	4.5	3.9
OPEC	7.0	6.5	5.8	6.1	5.0	1.0	3.8	2.1	5.4	2.2	2.6
China	10.1	10.4	11.1	13.0	9.0	8.7	10.3	9.3	7.7	7.7	7.4
FSU	8.4	6.6	8.2	8.6	5.3	-7.2	4.6	5.1	3.6	2.2	1
Total World (%)	**5.2**	**4.8**	**5.4**	**5.0**	**2.9**	**-0.8**	**4.9**	**3.6**	**3.1**	**3.3**	**3.3**

(*Source: OPEC Annual Report 2003-2015*)