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Contents

Steel Maker Companies' Strategies in Changing Environment and Possible Cooperation areas with Oil and Gas Producer Developing Countries

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ABSTRACT

Steel is among important raw materials for the production of wide variety of equipment for the oil and gas industry. For instance, steel pipe is an integral element in each segment of the value chain of the oil and gas industry from the drilling and completion of exploration and production wells to the transportation to refineries as well as in distribution networks carrying hydrocarbon fluids and natural gas.

The purpose of this research is to look into recent market developments in global steel market with the emphasis on the oil and gas industry oriented segment, defining main indicators affecting its price, obtaining knowledge about technologies and revealing the nomenclature of the products supplied by steelmaker companies to the oil and gas industry.

Finally, there will be an attempt to formulate strategies of the steel manufacturer companies in order to remain competitive in the changing business environment. Furthermore, I will try to define possible areas for cooperation between steel maker companies and oil and gas producing developing countries, especially in terms of energy industry.

1. INTRODUCTON

Steel is made from iron ore, iron scrap, coal (converted to coke), and limestone. It is an alloy of iron and carbon containing less than 2% carbon and 1% manganese and small amounts of silicon, phosphorus, sulphur and oxygen. It is one of the largest and most versatile bulk commodities in commercial use, having many structural applications and competing successfully with other structural materials, such as aluminum, plastics, and wood, for a variety of markets. Steel is not a single product. There are more than 3,500 different grades of steel with many different physical, chemical, and environmental properties.

The major forms of steel are sheet and strip, structural and plate, bars, pipes and tubes, wire and wire products, and tin mill products. Major markets for steel include the automotive, construction, machinery, equipment, containers and packaging, and oil and gas industries and steel service centers. (www.worldsteel.org)

Historically, steel production has followed the business cycle because a large share of steel is used for highly cyclical construction and consumer durables. [38]

While mini mills were emerging in the USA and Europe, Asia saw innovation in scale and throughput. Pursuing rapid growth in the 1960s and '70s Japan, followed closely by South Korea, developed massive state-of-the-art integrated facilities. These generated high-quality flat products from coils to coated and galvanized sheets, targeted at sectors such as automotive and appliance manufacturing. At the same time, economic reforms brought new energy to longer established parts of the industry. Many failing nationalized companies benefited from privatization. Sometimes this led to consolidation, but usually with an injection of capital investment in modernizing plants, processes and working practices. Throughout the 1980s and '90s, the entrepreneur Lakshmi Mittal built Mittal Steel, turning numerous loss-making nationalized companies into profitable private enterprises. Its 2006 merger with Arcelor created the world's largest steel producer, employing more than 260,000 people worldwide. The second instance came in 2007, with the purchase of Corus by Tata Steel. At the start of the 21st century, new technologies are firmly established in the steel industry. Continuous casting, along with

innovations in rolling and finishing, have brought major efficiency gains while reducing the industry's demands on energy for heat and water for cooling. By the end of 2011, China was by far the world's largest steel producer, with an output of just over 680 million tons and much of this production goes to support China's rapid urban development. [27]

Nevertheless, in accordance with OECD report on steel market developments in the 2nd quarter of 2015, the outlook for the steel sector remains weak. (Sekiguchi, 2015)

The relatively weak growth in global output is associated with a general slowdown in industrial activity. According to data from Netherlands Bureau for Economic Policy Analysis (CPB), world industrial production growth has slowed since May 2014, with industrial activity weakening in both advanced economies as well as emerging and developing economies.

Looking ahead, the latest OECD Composite Leading Indicators (CLIs) indicators, released in March 2015, show growth momentum picking up slightly in the euro area but remaining stable in other major economies and the OECD area as a whole. More specifically, the CLIs point to an improved outlook for major European economies such as Germany, France and Italy, as well as stable growth for other major economies, including the United States and China. The three-year period from 2014 to 2016 is expected to be characterized by exceptionally slow global steel demand growth. According to the April 2015 forecasts of the World Steel Association, global apparent steel use is expected to grow by only 0.5% to 1544.4 million metric tonnes (mmt) in 2015 and by 1.4% to 1565.5 mmt in 2016, reflecting the slowdown of China's steel demand and moderate demand developments in many emerging and advanced economies[1] (Table 1).

OECD economies generally exhibit lower steel intensities as a result of their mature economies, where e.g. services play an important role in economic output. Conversely, China has one of the highest steel intensities in the world; Chinese steel intensity is eight times that of Japan and over 15 times that of the United States. Compared to other regions, ASEAN economies also have higher steel intensity levels thanks to growth in manufacturing industries and increased investment in fixed assets. At the same time after three decades of extraordinary economic development, it appears that China is now shifting to a lower but still rapid and likely

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[1] Sekiguchi, N., (2015), Steel market developments, 2nd quarter 2015, OECD Publications, 2 rue André-Pascal, 75775 Paris, Cedex 16, France, p.3;

more sustainable growth path, the so-called the "New Normal".[2]

Steel products are widely used in plants for production and use of energy resources, represented by petroleum and natural gas (development, extraction and production, transportation, refining plants and electric power facilities). Steel materials are used in various forms and must provide high levels of performance and quality. The conditions in which oil and gas companies operate today have become increasingly complex in the quest to find and exploit new reserves, placing extraordinary demands on pipe manufacturers and service providers. Quality and reliability are critical factors for an industry where investments involve major economic, human and environmental risks.
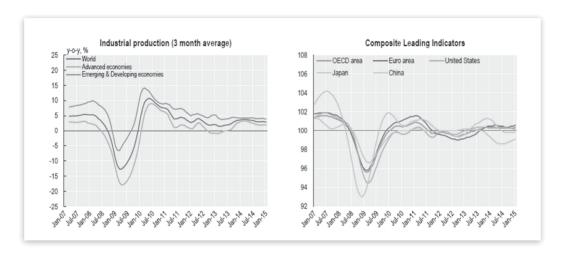

Figure 1. Industrial production and composite leading indicators[3]

Firms that have traditionally been in the steel business are not really in business to make steel, but to make profits. As a result, companies pursue some strategies to remain competitive in the market, such as decreasing their costs or product differentiation by offering premium products to their customers and increasing market share.

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[2] Sekiguchi, N. (2015), Steel market developments, 2nd quarter 2015, OECD Publications, 2 rue André-Pascal, 75775 Paris, Cedex 16, France, p.10;

[3] Source: Netherlands Bureau for Economic Policy Analysis (CPB) for industrial production and OECD for composite indicators.

Table 1. Latest forecasts of regional apparent steel use by World Steel Association[4]

	2007	2014		2015 (f)		2016 (f)		2015 (f) Growth rates, %	2016 (f) Growth rates, %	2015 (f) Contribution to growth, %	2016 (f) Contribution to growth, %
	Volume	Volume	07=100	Volume	07=100	Volume	07=100				
European Union (28)	200.5	146.8	73	149.9	75	154.1	77	2.1	2.8	0.2	0.3
Other Europe	30.4	37.0	122	38.0	125	38.5	127	2.8	1.4	0.1	0.0
CIS	56.4	56.5	100	52.4	93	52.2	93	-7.3	-0.3	-0.3	0.0
NAFTA	140.9	144.6	103	143.3	102	145.1	103	-0.9	1.3	-0.1	0.1
Central and South America	41.3	48.1	117	46.5	113	48.1	116	-3.4	3.4	-0.1	0.1
Africa	22.8	36.9	162	39.6	174	41.5	182	7.4	4.9	0.2	0.1
Middle East	43.8	51.9	118	53.3	122	55.6	127	2.8	4.2	0.1	0.1
Asia and Oceania	685.4	1015.6	148	1021.5	149	1030.4	150	0.6	0.9	0.4	0.6
China	418.4	710.8	170	707.2	169	703.7	168	-0.5	-0.5	-0.2	-0.2
World	1221.5	1537.3	126	1544.4	126	1565.5	128	0.5	1.4	-	-
World (excl. China)	803.0	826.6	103	837.2	104	861.8	107	1.3	2.9	-	-

Notes: Explanation of colour: ■ : Decrease year-on-year.
Source: OECD based on data from the World Steel Association.

Therefore, the following research questions will be addressed in this research:

• *What are the main trends in the current steel market?*

• *What strategies should be pursued by the steel manufacturing companies in the changing economic environment?*

• *What are the indicators or variables that can affect the price for steel and steel products?*

• *What are the areas for possible cooperation between steelmaker companies and oil and gas producing developing countries?*

2. OVERVIEW OF GLOBAL STEEL MARKET

In the face of increasing globalization, one of the main directions of restructuring the global steel industry was deemed the process of mergers and acquisitions in order to enhance sustainability and competitiveness.

China, India, Brazil, with the beginning of the new millennium, became the leaders in terms of gross domestic product, based on the development of basic industries - especially metallurgy.

The top thirty ranking of steel companies today, mostly occupied by Chinese companies,

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[4] Source: Sekiguchi (2015)

and their immediate actions aimed at further integration of the industry and to capture a greater share of the world market. (Urekeshov, 2012)

The economies of major economies are expected to continue to grow at a moderate pace during 2015-2016, while inflation and interest rates remain low owing to greater financial stability. According to the OECD's Interim Economic Assessment released in March 2015 (OECD, 2015a), lower oil prices and the effects of monetary policy easing will raise economic growth in the world's major economies. The euro area economy is starting to emerge from a period of stagnation, with GDP expected to grow by 1.4% in 2015 and 2.0% in 2016, up from 0.9% in 2014. US GDP growth is forecasted to grow by 3.1% in 2015 and by 3.0% in 2016, while Japan is projected to grow by 1.0% in 2015 and 1.4% in 2016.[1]

The global Purchasing Managers' Index (PMI) for steel, compiled monthly by Markit Economics, has declined to 49.4 points in March 2015 which is the below the 50-point threshold between expansion and contraction in business activity. At the same time there is an expectation of output growth in major steel-consuming industries in 2015-2016:[1]

- *Construction.* The construction sector is the largest steel-consuming sector, accounting for 52.2% of global steel use in 2013 (worldsteel, 2014). At a global level, construction output is expected to slow down from 3.3% in 2014 to 2.6% in 2015 and then to bounce back to 3.6% in 2016. Construction output during 2015-2016 is forecast to surpass the growth rate observed in 2014 in the EU, NAFTA, Africa and India, while in the CIS region it is expected to stagnate. Chinese construction output growth is expected to slow down and is forecast to rise by 4.3% in 2015 and 6.0% in 2016, below the 8.8% achieved in 2014.

- *Automotive.* Automotive is also a key steel-consuming sector, absorbing 11.6% of global steel use (worldsteel, 2014). The growth of the automotive sector in the world as a whole is forecasted at 3.5% in 2015 and 3.0% in 2016, slowing from a 5.1% in 2014. Automotive output in 2015 is expected to recover from negative growth rates in regions such as ASEAN and India. In the EU, output is expected to grow at a more moderate pace in 2015 and 2016. In NAFTA, automotive output is forecast to continue to increase in 2015 and 2016. Chinese automotive output showed robust growth (12.0%) in 2014, but is expected to slow down to 7.6% in 2015 and 6.6% in 2016.

- *Machinery.* Machinery accounted for 14.2% of global steel use in 2013 (worldsteel, 2014),

and output growth in 2015 is expected to outperform 2014, though it is forecast to decelerate in 2016. In Europe, the pace of the recovery between 2015 and 2016 is expected to be stronger, and in Latin America the sector is expected to show a tendency to recover in the coming two years. In China, growth of the machinery sector is expected to slow down in 2015 and 2016."

Due to weak steel demand in 2015 and 2016, global steel intensity is expected to decrease from 23.2 tonnes per million of USD in 2014, to 22.6 tonnes per million of USD in 2015 and 22.2 tonnes per million of USD in 2016. An important question that arises is whether the decline in Chinese steel intensity is a secular trend, reflecting ongoing structural changes taking place in the economy, or whether it is cyclical, and to what extent it will be offset in the future by rising intensities elsewhere.

Although many analysts had previously predicted that steel demand/production in China would peak around 2020 or 2025, now that point could be reached much sooner. Major mining companies expect China's steel production to continue to increase until the mid-2020s. However, China's Ministry of Industry and Information Technology has noted that China's steel consumption has already reached its peak and has stabilized, with this new phase referred to as the "New Normal'' (MIIT, 2015).

The latest steel demand data from China seem to support this notion — China's crude steel consumption dropped by 3.4% to 738.3 mmt in 2014 for the first time in more than a decade amid a property market slowdown.

According to the OECD's latest Economic Survey of China, China's economic growth is projected to remain moderate during 2015-2016 in line with slower investment growth, although still high in international comparison. A key development is the ongoing correction taking place in real estate investment, which accounts for 19% of total fixed investment in China. Investment in upstream industries, including steel, cement and construction materials, has also slowed (OECD, 2015b).

China's output growth is likely to rely less on higher FAI in the future, as steps are taken to shift from an investment-driven economy to a consumption-driven economy (WSJ, 2015). In addition, with expected declines in aggregate investment (GFCF), steel consumption intensity

is also likely to decrease.

Although the share of services in value added (excluding construction and utilities) has increased to 46.1%, and has recently overtaken the share of manufacturing, it still remains low compared to OECD and some emerging economies. If China follows a path similar to what developed economies experienced in the past, then a decline in steel intensity would be expected over time as the country becomes more dependent on services as a source of growth.

According to the Secretariat's calculations, regions that are currently net importers of steel products are expected to record the largest capacity increases, with Asia and the Middle East expected to lead the capacity expansions (OECD, 2015c).

Global crude steel production grew by only 1.0% to 1 665.2 mmt in 2014, driven by China's slowdown and modest growth in developed economies, though still a record-high level of steel production worldwide. Steel production increased slightly in advanced economies: 1.8% in the European Union, 1.5% in the United States and 0.1% in Japan. In 2014, Chinese steel production increased by 0.1% to 822.7 mmt, a significant slowdown from 12.4% observed in 2013. As a result, the Chinese share of global production decreased from 49.8% in 2013 to 49.4% in 2014. Some industry analysts note that the slower growth rate in China was caused by its softer economic performance and the new environmental protection law that came into effect in January 2015 is likely to have a significant influence on the country's future steel supply. In 2014, the Middle East was the fastest-growing steelmaking region with a 7.6% growth rate, while Ukrainian crude steel production in 2014 plunged by 17.1% below 30 mmt for the first time in five years, to a large extent due to the Ukrainian crisis.

Weaker steel demand, lower prices, and greater competition in the global steel market have caused major steel-producing countries to cut steel production in recent months.

Lower domestic prices in China and mounting financial difficulties have caused several Chinese mills to stop production of their blast furnaces and to initiate maintenance in recent months.

In the rest of the world, crude steel production was 810.8 mmt in the first quarter of 2015, in annualised terms, down 1.9% compared to the previous year. In contrast, Indian production has grown for 17 months in a row, and the country has overtaken the United States to become the third largest steelmaking country. (Sekiguchi, 2015)

Despite continued turbulence around the world in 2014, it has been another record year for the steel industry. Crude steel production totaled 1,665 million tonnes (Mt), an increase of 1% compared to 2013.

2014 also saw the emergence of a new phase in steel markets. For the past decade, the steel industry was dominated by events in China. The evidence is that the steel industry is now entering a period of pause before undoubtedly picking up again when markets other than China drive new demand. Nobody can predict exactly when or where. Today, China represents around 48% of the global market for steel. This will decline in years to come.

Table 2.

Years	World
1950	189
1955	270
1960	347
1965	456
1970	595
1975	644
1980	717
1985	719
1990	770
1995	753
2000	850
2001	852
2002	905
2003	971
2004	1063
2005	1148
2006	1250
2007	1348
2008	1343
2009	1238
2010	1433
2011	1537
2012	1559
2013	1649
2014	1665

Table 3.

	Company	Tonnage
1	ArcelorMittal	98.09
2	NSSMC	49.30
3	HebeiSteel Group	47.09
4	Baosteel Group	43.35
5	POSCO	41.43
6	Shagang Group	35.33
7	Ansteel Group	34.35
8	Wuhan Steel Group	33.05
9	JFE	31.41
10	Shougang Group	30.78

Table 4.

	Country	Tonnage
1	China	822.7
2	Japan	110.7
3	US	88.2
4	India	86.5
5	South Korea	71.5
6	Russia	71.5
7	Germany	42.9
8	Turkey	34.0
9	Brazil	33.9
10	Ukraine	27.2

Table 2: World crude steel production 1950-2014 (in million tonnes);

Table 3: Top steel producing companies 2014 (million tonnes crude steel production);

Table 4: Major steel producing countries, 2014(million tonnes crude steel production).

The striking points from tables 2-4 is the fact that ArcelorMittal produces two times more steel than the second ranked NSSMC. In the same vein, the largest steel producer country ‒ China produces 8 times more volume of steel than the follower country Japan. The protracted downturn in global steel market continues deteriorating the steel industry margins. Chronic overcapacity and volatility of raw material prices are the most influential and uncertain factors that shape the profitability of steel producers.

Analysis highlighted high value-added product development, quasi-vertical integration via supply contracts, and industry cooperation for demolishment of obsolete excess capacities as viable options, which could provide a serious enhancement of steel industry performance in most of the scenarios.

Despite a vivid recovery in volumes, the steel industry economic performance had declined significantly since "The Great Recession" with the steel industry ranked among the least profitable industries in most economies. Roughly 65 % of large steel players were operating with negative cash flows versus 30‒40 % before the crisis (Mareels 2013). Apart from the demand volatility, one can point out a few basic intrinsic forces periodically taking the steel industry in distressed situation: chronic overcapacity, growing pressure from the substitutes, increased volatility in raw material prices, and high fragmentation of the industry.

The high level of excess capacity is considered to be the major cause of the steel industry's weak financial performance (Wörtler et al. 2010). Since the recent "Great Recession" overcapacity has grown up to 25 %, as a consequence of slowing demand and high investment in new capacities. Actually, overcapacity is a rather stable phenomenon. It is very difficult to reduce installed capacities because of high exit costs, inflexible nature of the production process at the integrated steel plants, and political and social sensitivity (Woertler et al. 2002). The problem is exacerbated by permanent productivity improvements at installed capacities via debottlenecking, product mix optimization, and new plans of capacity expansion. Demand growth lags behind the ramp up of capacities not only because of sluggish GDP development in the mature markets and China's deceleration. Other reasons are a structural change of GDP growth in favor of less steel-intensive sectors and growing pressure from the steel substitutes.

3. Technological development in steel making processes AND PRODUCTS FOR of oil and gas INDUSTRY

Key raw materials needed in steelmaking include iron ore, coal, limestone and recycled steel. The two main steel production routes and their related inputs are:

- "The integrated steelmaking route, based on the blast furnace (BF) and basic oxygen furnace (BOF), which uses raw materials including iron ore, coal, limestone and recycled steel. On average, this route uses 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of recycled steel to produce 1,000 kg of crude steel.
- The electric arc furnace (EAF) route uses primarily recycled steels and direct reduced iron (DRI) or hot metal and electricity. On average, the recycled steel-EAF route uses 880 kg of recycled steel, 16 kg of coal and 64 kg of limestone to produce 1,000 kg of crude steel."[5]

Depending on the plant configuration and availability of recycled steel, other sources of metallic iron such as direct-reduced iron (DRI) or hot metal can also be used. Additives, such as alloys, are used to adjust the steel to the desired chemical composition. Electrical energy can be supplemented with oxygen injected into the EAF. Downstream process stages, such as casting, reheating and rolling, are similar to those found in the BF-BOF route. About 29% of steel is produced via the EAF route. Another steelmaking technology, the open hearth furnace (OHF), makes up about 1% of global steel production. The OHF process is very energy intensive and is in decline owing to its environmental and economic disadvantages. Only four furnaces of this type are known to be in operation. (www.worldsteel.org)

Steel is basically an alloy formed by iron ore and coal. Iron ore is essential for the production of steel, which in turn is essential in maintaining a strong industrial base. 98% of mined iron ore is used to make steel. Iron is one of the most abundant metallic elements. Its oxides, or ores, make up about 5% of the earth's crust.

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[5] Steel and raw materials, Fact sheet, World Steel Association, p.1

- Average iron content for high-grade ores is 60% to 65%, after taking into account other naturally-occurring impurities.
- Iron ore is mined in about 50 countries. The majority of iron ore is mined in Brazil, Australia, China, India, the US and Russia.
- Australia and Brazil together dominate the world's iron ore exports, each having about one-third of total exports.
- Worldwide iron ore resources are estimated to exceed 800 billion tons of crude ore, containing more than 230 billion tons of iron.[6]

As iron occurs only as iron oxides in the earth's crust, the ores must be converted, or 'reduced', using carbon. The primary source of this carbon is coking coal. Coal is a key raw material in steel production.

Coal is primarily used as a solid fuel to produce electricity and heat through combustion. Coke, made by carburising coal (i.e. heating in the absence of oxygen at high temperatures), is the primary reducing agent of iron ore. Coke reduces iron ore to molten iron saturated with carbon, called hot metal.

About 30% of coal can be saved by injecting fine coal particles into the blast furnace, a technology called Pulverised Coal Injection (PCI). One tonne of PCI coal used for steel production displaces about 1.4 tonnes of coking coal. Around 1.2 billion tons of coal is used in global steel production, which is around 15% of total coal consumption worldwide. Recycled steel (scrap) can be collected from excess material in steel facilities and foundries (home scrap) or downstream production processes (industrial scrap) and from discarded products (obsolete scrap). Recycled steel is a key input needed for all steelmaking process routes. EAFs can be charged with up to 100% of recycled steel and basic oxygen furnaces with approximately 30%. Recycling this steel accounts for significant energy and raw material savings: over 1,400 kg of iron ore, 740 kg of coal, and 120 kg of limestone are saved for every 1,000 kg of steel scrap made into new steel.[7]

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[6] Steel and raw materials, Fact sheet, World Steel Association, p.1
[7] Steel and raw materials, Fact sheet, World Steel Association, p.1

3.1 Steel in energy

Whether energy is produced from fossil fuels, nuclear or renewables, the production process and distribution routes relies on steel. It is used in electricity pylons, to make offshore oil platforms and it reinforces concrete structures in hydroelectric power stations. No generator, transformer or electric motor could be operated without electrical steels needed to transform electrical power into usable energy. Steel also plays a key role in converting solar energy into electricity or hot water. It is used as a base for solar thermal-panels and in pumps, tanks and heat exchangers and to fabricate wave energy devices. Offshore oil rigs, bridges, civil engineering and construction machines, rail carriages, tanks and pressure vessels, nuclear, thermal and hydroelectric plants – all these applications benefit from the attributes of modern steels.

Steel is such a well-used material in modern structures that we are often unaware of the design efficiencies they embody. A prime example is the tubular steel towers used for the wind turbines now being installed around the world. Generally, taller towers offer greater energy generating efficiency, since wind speeds increase at higher altitudes. The new steels used in the construction of such towers offer much higher strength-per-unit weight ratios than other materials, so taller towers can be erected with much less stress on the structure. Lower weight also enables these towers to be manufactured in sections of up to 30 m, then assembled and installed on site. Ongoing research continues to produce new steels that are even stronger than their predecessors, and thus will minimize the mass of future towers. As a result, tower weights (per installed power in kW) have declined by about 50% during the past 10 years. A typical modern tower in the Horns Rev wind farm in Denmark is 70 m high and weighs only 140 tonnes. This represents a 50% reduction in weight and a saving of more than 200 tonnes of CO_2 for each tower compared to its predecessors of just 10 years ago.[8]

A particular type of plate is available with a designed-in resistance to corrosion, ideal for building oil tankers. Such steels make possible much lighter vessels than before, or larger-capacity vessels for the same weight, offering significant opportunities to save on fuel consumption and hence CO_2.

High temperature-resistant steels have made efficiency in steam power plants possible and have the potential to be developed and employed even further. Combined heat and power (CHP)

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[8] Advanced steel applications, Factsheet, World Steel Association, p.2;

allows waste heat in power plants to be used for power generation as heat energy, increasing the overall efficiency of fossil fuel power plants. The waste heat is transported exclusively in steel pipes. (www.worldsteel.org)

Advanced technologies maximize the efficiency of production and minimize emissions of CO_2 to atmosphere. CO_2 generated in the steel industry results mostly from the chemical interaction between coal and coke (carbon) and iron ore in a blast furnace. This process is called ore reduction and produces hot metal which is then converted into steel. There is no large-scale commercially available substitute for replacing all the carbon in iron and steel making.

According to Worldsteel Association in terms of technology transfer they organize regular information exchange among members through projects, workshops, conferences, and expert groups on technology, environment, LCA, safety committees and also by benchmarking energy intensity, emission intensity, reliability and safe practices. Furthermore, Worldsteel Association produces technical reports on major subjects impacting the steel industry.

They have initiated "The CO_2 breakthrough programme" which identifies steelmaking technologies that hold the promise of significant reductions in CO_2 emissions. They explore their feasibility on various scales, from lab work only to small pilot plant developments and eventually commercial sized implementation or using existing plants to test the improvement.

They put forward five possible directions which are under examination:

1. CCS – use of carbon capture and storage technology (CCS): The goal is to produce steel with lower CO_2 emissions to the atmosphere by capturing the CO_2 produced in the iron and steel making process, injecting it into existing oil fields for enhanced oil recovery (EOR) while at the same time storing it;

2. Coal – would continue to be used as a reducing agent but the ensuing CO_2 would have to be captured and stored. The approach is similar to the power industry's effort to cut emissions from fossil fuel power plants, although the steel production solutions propose oxygen operation and in-process CO_2 capture rather than oxyfuel combustion and pre- or post-combustion capture. Ironmaking solutions range from the blast furnace, modified to accommodate CCS as in the ULCOS 'top gas recycling blast furnace', to smelting reduction processes such as HIsarna, Finex, etc., also similarly re-designed.

3. Hydrogen – could be used as a reducing agent, as its oxidation produces only water. Hydrogen, either pure, as a synthesis gas (syngas) produced by reforming methane or as natural gas, can be used in conventional direct-reduction reactors or in more futuristic flash reactors. Gas reforming (both need high pressure steam or carbon free electricity otherwise it would defeat the purpose). Both may include CCS at their own level.

4. Biomass – can be used to generate the reducing agent, either from charcoal for example or syngas. Biomass in such a scheme would need to be grown effectively near the place of use and in sufficient quantities to make it economically usable and repeatable. Interest in biomass is strong in Brazil, Australia, Canada and Europe. Biomass can be added as charcoal in the blast furnaces, added to the coke oven charge, burned as fuel in steelmaking reactors or used in direct reduction as syngas etc.

5. CCU - CO_2 capture and utilization (CCU) technology in iron and steel industry can consist of the unit processes: CO_2 capture, waste heat recovery from flue gas and molten steelmaking slag and CO_2 utilization. CCU could be critical in the near-term to support longer-term objectives for deployment of CCS in steel industry from the year 2035 onwards. Emission reduction pathways through which CCU technologies can reduce emissions of CO_2 to the atmosphere include: CO_2 to fuels, enhanced commodity production, enhanced hydrocarbon production, CO_2 mineralization and chemicals production.[9]

The various exploratory programmes have already identified more than 40 technologies of which seven programmes show promise.

Table 5. Breakthrough programmes past and ongoing[10]

Programme	Involving	Purpose	Best results
AISI - technology roadmap programme	Public-private partnership between AISI and the US Department of Energy's (DOE), Office of Industrial Technology)	Joint DOE/AISI collaborative programme designed to (1) increase energy efficiency, (2) increase competitiveness of the North American steel industry, (3) improve the environment. Different to other programmes because steel programme is required to pay back the federal cost sharing.	(1) Suspension hydrogen reduction of Iron oxide concentrate; (2) Molten oxide electrolysis.

Burchart-Korol D. et al., (2015), Innovative technologies for greenhouse gas emission reduction in steel production, Review paper to be published in METALURGIJA 55 (2016) 1, p. 121;
Source: www.worldsteel.org;

Programme	Involving	Purpose	Best results
Baosteel Programme	Baosteel (China)	Objective is to reduce emissions from flares	(1) Photovoltaic cells (2) Ethanol production from BOF gas (LanzaTech).
Australian programme	BlueScope Steel and OneSteel, CSIRO coordination (Australia)	In Australia, CSIRO is working with BlueScope and OneSteel on two projects aimed at cutting CO_2 emissions: biomass, which uses renewable carbon derived from biomass in steel manufacturing and heat recovery from molten slags through dry granulation, which captures the waste heat released from slag cooling, thus reducing CO_2 emissions. These programmes have received large support from the Australian government.	(1) Cut CO_2 emissions through the use of biomass and by-products.
COURSE50	Japan Iron and Steel Federation (JISF), Japanese Ministry of Economy, Trade and Industry	Objective is to develop innovative technologies to help solve global environmental problems. Includes R&D projects, public relations activities and promotes industry/institute cooperation.	(1) Scenario-making for global warming mitigation; (2) CO_2 separation, capture and storage; (3) CO_2 fixation by plants and its effective use (4) Hydrogen reduction has been tested with interesting results, limits have been identified as well.
China Steel Corporation (CSC)	Taiwan CCS Alliance coordination (Taiwan)	The Alliance is focusing their research activities on two main technologies: the oxy fuel burner technology which aims at purifying CO_2 by burning without nitrogen content and the chemical absorption pilot plant which seeks to further decrease energy consumption per unit of CO_2 captured. Additionally, academic cooperation projects in CSC include BOF slag carbonation and microalgae carbon fixation.	(1) CO_2 purification; (2) Energy use reduction; (3) BOF slag carbonation and microalgae carbon fixation.
POSCO CO2 breakthrough Framework	POSCO, RIST, POSLAB, POSTECH	Objective is to find new solutions for CO_2 emission reduction in the steel industry, and climate change adaptation using steelmaking by-products. The framework consists of six projects: (1) Pre-reduction & heat recovery of hot sinter, (2) CO_2 absorption using ammonia solution, (3) Bio-slag utilisation for the restoration of marine enviornments, (4) Hydrogen production using coke oven gas and wastes, (5) Iron ore reduction using hydrogen-enriched syngas, and (6) Carbon-lean FINEX process.	(1) CO_2 absorption using ammonia solution; (2) Carbon-lean FINEX process.
ULCOS - Ultra-low carbon dioxide steelmaking (EU)	All major EU steel companies, energy and engineering partners, research institutes and universities. Also supported by the European Commission	Cooperative R&D initiative to research radical reductions in carbon dioxide (CO_2) emissions from steel production. Includes process science, engineering, economics and foresight studies in climate change.	Top gas recycling blast furnace with CO_2 capture and storage (CCS); (2) HIsarna with CCS; (3) Advanced direct reduction with CCS; (4) Electrolysis.

The coal-based ironmaking technologies associated with CCS are the most likely candidates for early maturity. Hydrogen technology is further into the future, as it will require re-engineering of steel production and the development of new processes from first principles. Biomass solutions are probably in the intermediate future.

4. THE price of steel AND FACTORS AFFECTING IT

This chapter is dedicated to the revealing the main factors that may have an effect on the price of steel. Furthermore, the empirical analysis in order to find out the magnitude and direction of their effect will be carried out.

Although steel production growth has slowed, the combined effects of weak steel demand and falling raw material prices have placed downward pressure on steel prices. The world steel price index P has been trending downwards since the second quarter of 2011. It decreased to 158 points in April 2015, 44% lower than its post-crisis peak in April 2011.[11]

4.1 Overview of the factors that may have an effect on the steel price formation

First of all, intuitively we can think of prices for raw materials as having the foremost and direct effect on the formation of steel market prices.

According to experts the prices for raw materials are likely to remain comparatively low over the next year or two. The iron ore spot price (the reference price being Chinese imports of iron ore from Australia) has been below USD 100 per tonne since May 2014, and fell to USD 49 per tonne in April 2015. (Sekiguchi, 2015)

According to data from the International Steel Statistics Bureau (ISSB), iron ore exports from major exporting countries such as Australia and Brazil reached a record-high in 2014. As a result of 89% decline to its exports compared with 2009 India was surpassed by South Africa and Canada in 2014. In addition due to expansion of steel production and increased requirements for iron ore India became importer of iron ore.

In the same vein hard coking coal spot prices from Australia after decline from February

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[11] www.worldsteelprices.com

2011 up to 2014 used to remain relatively stable until the fall down to USD 95 per tonne in April 2015, representing 76.3% decrease in comparison with peak that occurred in July 2008. Unlike iron ore, the coal market balance is expected to tighten from 2016 onwards, as a period of oversupply comes to an end through the closure of high cost mining operations and growing steel production in China and India (BREE, 2015).

The reference price of scrap (FOB Rotterdam) fluctuated around USD 350 per tonne, from mid-2012 until September 2014. Although scrap prices have declined significantly since October 2014, they rose slightly in March and then remained steady at USD 230 per tonne in April 2015. Some divergence has, however, been observed across different markets.

Among other factors affecting the steel prices rather than raw materials is deemed to be by experts and analysts are oil prices. Lower oil prices are having important effect on demand and prices for specific steel products used in the oil and gas industry, with seamless and welded pipe prices having declined since the second half of 2014. For example, the North American imported welded pipe price (oil country tubular goods, or "OCTG") decreased to USD 909.5 per tonne in April 2015, a level 29.8% lower than the post-crisis peak reached in August 2011. The sensitivity of metal prices to global economic activity is usually greater than that of oil prices, but the recent oil price trend shows a faster decline than metal prices. Falling oil prices have caused some pipe destocking, decreases in pipe production, mill closures, layoffs and a deterioration of business earnings across several major steelmakers, as several large energy companies plan to delay or cancel projects and cut their capital spending (Platts, 2014).

Close correlation can be observed between oil prices and oil rig count numbers. For instance, the recent drop in oil prices has had a significant impact on drilling activity. The worldwide rig count was down from 3 597 in March 2014 to 2 557 in March 2015, reaching a level below 3 000 for two months in a row. Major energy companies have announced plans to cut their 2015 budgets, reduce their capital spending around 10-20% in 2015 and suspend or delay projects due to the recent fall in oil prices. For example, several large energy companies such as BP and Total announced that they will cut capital expenditure by about 10-20% in 2015. According to Platts, overall spending by six major companies (Shell, Total, BP, Statoil, Eni and BG Group) for 2015 is expected to amount to an estimated USD 115 billion, more than 10% down compared to 2014 (Platts, 2015).

Another factor that comes into mind in relation to the general economic theory is the demand for steel. The demand for both pipes and tubes and plates used for marine structures and for line pipes are highly vulnerable to fluctuations in oil prices. However, the effects of falling oil prices on aggregate steel demand are not easy to determine (JMD, 2015a) and will likely be felt differently across the wide range of steel products. On the one hand, lower oil prices reduce the demand for pipes (notably large diameter pipes) due to the postponement or cancellation of energy projects. In fact, demand for energy-related steel products has dropped sharply recently (JMD, 2015b), though the energy sector will play an important role in the long run (OECD, 2012, MBR, 2012). Although the shale oil revolution in the US has contributed to a 10% annual growth rate for pipe construction, the fall in oil prices has led to widespread destocking of pipe inventories due to delays or cancellations of shale oil projects (BREE, 2015).

On the other hand, lower oil prices may have a positive effect through higher household income, and could boost steel demand in some sectors such as machinery, chemicals and automotive (Platts, 2014).

As fuel oil prices drop in line with falling oil, freight rates have fallen sharply since the end of 2014. Lower freight costs could boost trade in raw materials and steel.
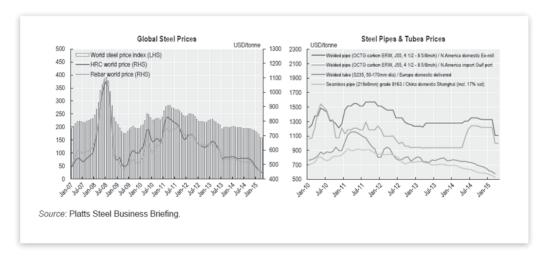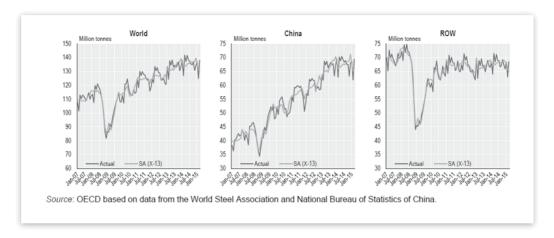

Figure 2. Key raw material price indicators.

Figure 3. Trends in crude steel production

In this part we will try to test empirically the factors that may have an effect on the steel price. Here is the model chosen for the analysis:

$$\text{Price of steel} = \beta 0 + \beta 1 (price\ of\ metallur gical\ coal) + \beta 2 (price\ of\ iron\ ore) + \beta 3 (price\ of\ steel\ scap) + \beta 4 (steel\ demand) + \beta 5 (oil\ price) + \beta 6 (freight\ rate) + \beta 7 (populatiion) + e$$

Dependent variable:

Price of steel: The dependent variable is expressed as annual average hot-rolled steel bar price. The source of data is US Energy Information Administration.

Independent variables:

Price of metallurgical coal: is defined in terms of bituminous coal, which is the main product for metallurgical coal. The data for this variable is derived from US Energy Information Administration.

Price of iron ore: is formulated in terms of annual Brazilian iron ore fines price and outsourced from USGS (US Geological survey).

Price of steel scrap: is expressed in annual average U.S. steel scrap price, USGS (US Geological survey) being a source of data.

Steel demand: is proxied by the apparent steel use in crude steel equivalent and collected from Steel Statistical Yearbooks of Worldsteel Association;

Oil price: is expressed in Brent oil prices in constant 2014 US dollars. The source of the data is the BP Statistical Review of World Energy 2015.

Freight rate: is presented as trip charter rates - Commodity Price Deflator. The data is borrowed from www.mgmt.purdue.edu/faculty/hummelsd/research/jep/data.html as references in the paper by Hummels D. (2007);

Population: is expressed as annual data on world population taken from the Worldbank dataset;

The analysis covers the period between 1976 to 2004.

All variables except Oil_Price_Adj and Freightrate were converted into logarithmic form to reveal directly the possible effect of the independent variables onto the dependent variable in percentage terms.

Table 6. Summary statistics

Variable	No. of Observations	Mean	Std. Dev.	Min	Max
Dependent Variable:					
LN_Steel_Price	28	2.882744	.1698221	2.426571	3.182212
Independent variables:					
LN_IronOre_Price	28	3.304634	.1126956	3.068053	3.504055
LN_Met_Coal_Price	28	3.689743	.2935892	3.303952	4.132764
LN_Steel_Cons	28	13.53071	.0919068	13.37999	13.78488
LN_Steelscrap_Price	28	4.530655	.2210886	4.13868	4.905497
Oil_Price_Adj	28	46.69997	24.29995	18.46782	105.8129
Freightrate	28	86.60744	10.06364	67.25585	100.9649
LN_POP	28	22.37046	.1327491	22.14361	22.5724

Table 7. Estimation results

Specification	(1)	(2)	(3)
Constant	-101.82*** (27.9)	-110.16*** (20.72)	0.34* (0.25)
LN_IronOre_Price	0.24 (0.33)		0.76*** (0.25)
LN_Met_Coal_Price	2.30*** (0.56)	2.33*** (0.47)	
LN_Steel_Cons	- 0.86* (0.44)	- 0.97** (0.36)	
LN_Steelscrap_Price	0.13 (0.13)		
Oil_Price_Adj	- 0.006*** (0.002)	- 0.005*** (0.001)	
Freightrate	0.001 (0.003)		
LN_POP	4.77*** (1.25)	5.27*** (0.89)	
F statistic	10.78	10.61	9.11
No. of observation	28	28	28
R2	0.6733	0.6485	0.2595

Note: *,**,*** shows the significance of coefficients at 10%, 5% and 1% respectively.

In general the signs of all coefficients came up as expected.

If we closely look into the estimation results the coefficients for iron ore and metallurgical coal are positive and while latter is significant in both models the former only in one of two models. The sign of the related coefficient in this case came up as expected owing to the fact that iron ore and metallurgical coal are two important raw materials in the steel production process and the increase in their price will inevitably result in the price rise for the steel.

Steel scrap coefficient is not significant, but positive. It may mean that the technology for recycling and re-use of steel scrap in the production process was not mature or not used widely and steel scrap serves just as by-product or waste of the steel production process.

Demand for steel has an inverse relationship with the price of steel. The result is in line with the economic theory. One percent increase (decrease) in the price of steel is expected in 0.86 percent decrease (increase) in the steel consumption or vice versa.

The negative relationship is observed between the price of steel and price of oil. Although the coefficient is very small and it may imply that lower oil price have a positive effect through higher household income, and could boost steel demand in some sectors such as machinery, chemicals and automotive.

Steel freight rate didn't appear significant. Probably the freight costs were not among the most decisive factors owing to the possibility that trading parties may have used to resort to long-term contractual arrangements in booking their transportation.

In accordance with economic theory and general intuition the price of the steel should increase with the increase in world population and results imply that 1 percent increase in global population is expected in approximately 5 percent increase in the steel price. That is logical because the increase in population is inevitably results in the increase in demand for infrastructure, transport and many other fields and products which entail further usage of steel.

There are several limitations to study such as the limited number of observations and exclusion of the period due from 2004 to date due to data availability regarding some of the variables under study.

Nevertheless, the model and results has endorsed the economic theory and general intuition in terms of the factors affecting the price of steel and their probable magnitude.

5. current trends in the industry and strategies for the global market players and searching for possible areas for cooperation with oil and gas producing developing countries

The steel value chain can be divided into four stages: First, the acquisition of primary resources; second, the production of steel, which can be further divided into the actual production of crude steel, reduction to steel, milling and refinement; third, trade and fourth, the processing of steel into steel products in the various branches of industry.

The fashionable trend in the global steel industry has been vertical integration. The various motives and causes of integration can be grouped under three main heads such as financial, economies in production or in organization (economies of scale) and resource.

The integrated industry obtains its supplies in each stage of production at a real cost which includes no margin of profit. More generally, however, every integrated concern has to face the problem of compromising between optimum technical efficiency at every stage and a balanced flow of output. The chief motive must be found elsewhere, and it undoubtedly lies, as is largely recognised in the industry itself, in strategy, or "resource." If we take the pig iron-steel stage as the central point, then much of the integration backwards can only be explained on this basis of desire to avoid extreme prices of materials in a boom, in some cases a desire to ensure continuity of supplies. The matter is especially important in that the cost of raw materials is a major item in total costs - 75 to 85 per cent particularly in the case of pig iron and close on 70 percent. Integration forwards arises from the need to ensure markets in a depression. Its development is closely linked with the existence of price agreements, always a notable feature of the industry. The strategy adopted has its basis in the maintenance of prices so far as is possible plus integration as a means of ensuring some market. (Dennison S.R., 1939)

The initial wave of globalization bypassed steel industry because of the capital investment and logistic costs involved with setting up cross-border operations. The situation turned for steel industry on the back of China's high speed growth after 2000. China's entry into the World Trade Organization and insatiable need for steel to supply the torrid pace of domestic construction spurred the Chinese steel industry, increasing demand from Western and Asian steel producers. At the same time, with iron ore and scrap commanding higher and higher prices, steel producers realized they needed a way to check growing input costs.

In 2002, large steel companies in France, Spain, and Luxembourg joined together to establish Arcelor. Consolidation helped Arcelor negotiate more favorable contracts, and expanded the scope of their business operations. (Kim, 2009)

The changing market and production structures have also given a new impetus to the structures of the sector at a corporate level. Because of sensitivity regarding freight costs, the steel industry is a regionally diversified industry. Furthermore, there is a strong regime of political regulation, which for many decades has ensured companies' national sales markets. The growth surge of the Asian markets has resulted in the appearance of some new faces on the global market stage. In 1998 the list of the 20 biggest companies included the names of two Chinese companies (Baoshan, Anshan) and one Indian company (SAIL), who managed to score

in the last couple of places on the list. Ten years later, steel companies from the emerging nations dominate the list.

The most significant event to arise during the reshaping of the structure of the industry was undoubtedly the rise of Mittal Steel, a company which, in 1989 in a highly decentralized industry, began to buy up steel plants that were in deficit or situated in peripheral regions. The company's goal was to become the lowest-priced supplier in every steel market. As a result, Mittal agreed on global strategies of company management, featuring regional limitations to specific markets. After becoming the largest steel company in 2005, Mittal merged with the Luxemburg company Arcelor in 2006. Ever since, ArcelorMittal has been by far the largest steel company worldwide. (Scheuplein, 2010)

The development of the iron ore market indicates that a secure, long-term supply of inexpensive iron ore has become a key factor for every steel producer. In theory, there are two alternatives available to companies. They can continue to secure their supply in an oligopolistic market where more bargaining power and political initiatives aimed at a broader supply structure are necessary, or they can embark on a route of backward integration and attempt to secure their iron ore supply by buying or establishing their own iron ore mines. The second strategy can be observed in its operation in emerging countries, especially in China. However, if one goes back a few decades, this strategy was also pursued by companies in the established industrial countries. On the other hand, European steel companies have taken the former approach over the past two decades. Today, they are virtually distancing themselves from an integration strategy. During the 1990s, the British, French and German steel companies at the time discontinued their existing participations in mining companies. The last German iron ore mining company, Ferteco, then the third-largest iron ore producer in Brazil, was sold by ThyssenKrupp to Vale in 2001 (Dalheimer 2001, 6). This was communicated as being a useful restriction within the framework of the shareholder value strategy which was to create resources for expansion in the core business area. From his viewpoint, funds were released by the divestment process with which the quality of steel could be improved and could be invested in the downstream stages of the value chain (Ameling, 2007b).

Two conditions are missing in Europe for a similar vertical integration strategy to develop: On the one hand, there is no similar growth process in the steel market and, on the other hand, the current production facilities are located a long way away from the European economic area.

In terms of oil and gas industry owing to the fact that the era of easy oil comes to an end the strategy directed towards the satisfaction of a need for premium products designed for use in hydrocarbon wells with difficult mining conditions and aggressive environments seems to be of those that capable of conveying success in the mid- and long-term. Oil and gas industry goes to the Far North, masters offshore fields, drills horizontal and directional wells.

Technological development and innovation is relevant in all of the fields of the economy and steelmaking industry is not an exception. New innovations such as the twin shell electric arc furnace would overhaul. Strip casting technology was the next leap forward that would produce think strips of steel and eliminate slab-casting stage and rolling in a hot mill. Many developed countries had developments underway. Other advances include advanced metallurgical practices, and process control sensors and refinements in casting and rolling. Advanced solutions to problems are a key advantage for viability which should be embedded across the organizational culture for impact.

The environment protection and struggle to stop the climate change and curb GHG emission is an especially hot topic in an international agenda. COP21 summit held recently in France's capital Paris is likely to set up roadmap in terms of the involvement of all stakeholders in this process via creation of mandatory emission reduction targets that has been proposed by every and each country of the international community. Environment protection should be a corporate goal of every enterprise working in steel or metallurgy field to show the example of responsibility towards prevention of waste and emissions pressured by various individuals and organizing bodies.

One more important strategic direction is the development of sustainable competencies such as: ability to transform process, save resource and energy, carry out utilization of the three wastes (i.e. waste gas, waste water and industrial residue), change by-product into a kind of resource and pushing for clean production.

A steelmaker needs to position to succeed in this changing environment. Critically, willingness to adapt quick and precise to 'unnatural' changes are keys to survival. The way to do that is to assess where the company is right now, move into a stronger position and perceive challenges as a necessary to become a market leader or niche player.

The focus strategy should concentrate on segments that attempt to achieve either a cost advantage or differentiation. The costs gap widens, volumes are lower, and customers are better served, moving the chain value up. Another niche area could be focused on production methods that attach societal responsibilities to sustaining activities, reducing unwanted pollutants, propaganda and conflicts with the community.

Overall, the risk of niche emphasis is the difficult art of balancing costs and differentiation, since differentiation amounts to higher costs in research, talent sourcing, marketing and servicing of customers.

Additionally, differentiation in reputation and trust of reliable products and services are crucial for safety and social concerns (being the objective).

Another important strategy is a responsible management of natural resources.[12]

Slag is the main steelmaking by-product; it is mostly used in cement production, reducing CO_2 emissions by around 50%. It can also be used in roads (substituting aggregates), as fertilizer (slag rich in phosphate, silicate, magnesium, lime, manganese and iron), and in coastal marine blocks to facilitate coral growth thereby improving the ocean environment. Gases from iron- and steelmaking (for example, from the coke oven, BF or BOF) once cleaned, are used internally to produce steam and electricity reducing the demand for externally-produced electricity. Gases can be fully reused within the steel production site, and can provide up to 60% of the site's power. Alternatively, gases can also be sold for power generation.[8]

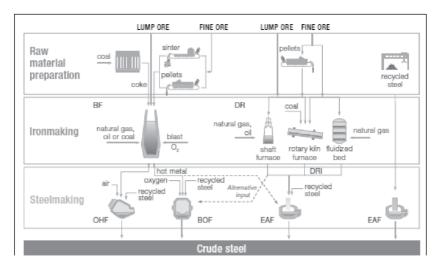[12] Steel and raw materials, Factsheet, World Steel Association, p.2;

Figure 4. Steelmaking routes.

Improvements in energy efficiency as it constitutes from 20% to 40% of total cost of steel production in some countries is going to result in reduced production costs and thereby improved competitiveness. The energy efficiency of steelmaking facilities vary depending on production route, type of iron ore and coal used, the steel product mix, operation control technology, and material efficiency.

New area of possibility is the recovery and utilization of the phosphorus and sulfur wastes form the steel production process. The phosphorus (P) and sulfur (S) contamination in the steelmaking process are due to their concentrations in the iron ore. In the case of food production, however, there is and will never be an alternative for phosphorus. Commercial food production is highly dependent on fertilizers, and all the positive assurances that the world has the ability to feed itself in the future assume a plentiful supply of phosphorus in the years to come. As such, the increase in the demand for food with the growth of the global population will be accompanied by an inevitable increase in the demand for phosphorus over time. In the steelmaking industry, on the other hand, phosphorus is simply regarded as an impurity which needs to be removed, due to its detrimental effects on the mechanical properties of steel. (Matsubae, K., et al., 2015)

As the reserves of high grade iron ore become depleted, the amount of phosphorus in the iron ore used in the steel industry will gradually rise, which will equate to higher amounts of

phosphorus with the potential to be recovered and utilized in the domestic market. The steelmakers have two options in the marketing of recovered phosphorus. One is to market it directly to the fertilizer or chemical industry. The other is to produce a value-added product, a phosphate fertilizer, for the market.

Another possible application and new business models is for example, a company that currently manufactures and 'sells' steel, or a third party, could find new business opportunities by becoming a 'reseller' of reused steel and providing a 'steel service'. This could be facilitated by its ownership of the database that enables it to know the whereabouts of the steel and to be able to warrant its properties and appropriateness for reuse in certain applications. (Ness, 2014) However, there are a number of barriers to reuse, including the lack of confidence of designers in the structural properties and performance of reused steel components. Anecdotally, the identification of materials to be re-used in the design phase is a significant factor in the uptake of re-use as there is no easily defined marketplace for salvaged materials. This situation is further exacerbated by the absence of procedures in the current design codes for determining the necessary properties for reclaimed steel.

Global strategic perspective analysis will be based was made by (Malanichev, 2015).

They put forward steel capacity utilization and raw material prices as the most influential factors of steel price and industry profitability (Malanichev and Vorobyev 2011).

Real-term commodity price shows a long-term downward trend in over the last century, which is related to new deposit development, a progress in mining technology and the superiority of income elasticity of demand for manufactured goods over primary commodities demand elasticity. On the other hand, some factors that kept raw material prices down historically, like the economies of scale, low cost energy, and development of new mineral deposits, may be losing steam and even reversing the direction (Humphreys 2013). Actually, mining and exploration become more expensive as new mines are found and developed in remote areas, sometimes with the lack of infrastructure and political stability. Nowadays, mineral deposits are found at deeper layers and have poorer quality, pushing raw material costs and prices higher and higher (OECD 2012). For instance, the average Fe content in China's iron ore mines has dropped from 28 to 21 % since 2004 (Lelong 2013).

Thus, cyclical and trend components of the long-run iron ore and coking coal prices are

rather uncertain. The same we can conclude about steelmaking capacity utilization, which is a function of steel consumption and capacity volume.
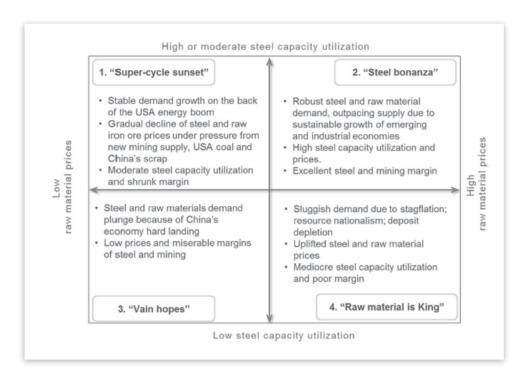

Figure 5. Scenario matrix[13)]

The fate of the second component of capacity utilization— steelmaking capacity volumes— is also murky. Emerging markets annually ramp up a few dozen of brand-new highly efficient steel-melting facilities, whereas demolishment of obsolete ineffective equipment across the world is procrastinated for various reasons, including possible state subsidies of ferrous metallurgy.

All four scenarios are considered to have equal probability to come true and include other key drivers, depicted in Fig. 5. The first "super-cycle sunset" scenario implies a gradual decline of steel and raw material prices on the back of abundant supply from the new mining projects, the growing coal exports from the USA, and lavish supply of obsolete ferrous scrap emerging in China. Inflated margin of the mining industry is gradually disappearing, whereas the steel

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13) Adopted from Malanichev (2015)

industry margin stays moderate and similar to the current level due to reduced capacity utilization. The second scenario is "steel bonanza". It outlines prospering, rather sustainably growing world economy as a result of a new cycle of leveraging at developed economies and consumption boom caused by resumed population growth in China. Increasing population and standards of life drives heightened steel and raw material consumption. Discoveries and developments of new iron ore and coking coal deposits drag behind growing demand. As a result, steel and mining industries enjoy high prices and profits. The third "vain hopes" scenario assumes China's hard lending that leads the whole world into prolonged stagnation with deflated prices and dramatic consequences for the steel and mining industries. The drop of China's infrastructure investments derails steel and raw material demand in the country and global markets. A problem with redundant capacity embraces both steel and mining industries. The glut of the products of these industries in the market keeps the prices on the bottom for a rather prolonged time. Last scenario is named "raw material is king" describes a world of stagflation stemmed from restricted mining supply. The latter is caused by the lack of discovery of new economically efficient deposits along with a policy of resource nationalism followed by some resource-rich countries. In spite of stagnation in demand, deposit depletion and worsening of geological conditions push the mining costs up. Inflated raw material prices support the steel ones, but sluggish demand causes the mediocre steel capacity utilization and poor margins. (Malanichev, 2015)

Thus, the driving forces of the first and fourth scenarios are supply shocks, whereas the second and third ones are explained by demand shocks. The profitability of steel industry is shrunk in all scenarios except for the second one mainly because of the chronic overcapacity and high-supply elasticity.

It should be noted that none of the scenarios would become a reality with the entire set of described details. It is highly probable that we would witness some combination of the described driving forces; at the same time, the key factors forming scenarios would take place.

In this section, seven strategic options are tested on each of the developed scenarios. Depending on option robustness, they are classified in a similar mode as it is done in Tugwell (2011). The most universal options that are effective for any scenario are called a "robust initiative". If the option is valid for most scenarios, it is classified as a reasonable bet. In the

50-50 situation, we denote the option as a bet, and if we can exit the option without considerable losses, we use a term flexible bet.

For simplicity, we assume that strategic options could be realized in a medium term under current market conditions, before any scenario unfolds and conditions change. We also do not make any assumptions on the period beyond the scenario scope (after 2025) to exclude complexity conditioned by the long-term price behavior.

The first strategic option is upstream integration. It implies the takeover of raw material asset in the production chain. The advantages of this strategy are based mainly on supply confidence and control of the raw material price volatility (Kudelko 2013). A market player can benefit from the strategy in case of heightened raw material prices in scenarios 2 and 4.

Contrary, acquisition of mining assets on the eve of iron ore and coking coal price decrease, according to scenarios 1 and 3, would destroy shareholder's value. So, the use of the strategy means betting on a corresponding favorable scenario.

However, there is a more flexible variant of the upstream integration strategy—supply contract, which could be classified as the flexible bet. It includes the development of long-term relationships with suppliers and making a special contract ensuring the shipments according to beforehand agreed volumes and price formula. Transaction costs of breaching the contract conditions are considered to be smaller than the disposal of distressed raw material assets in case of an unfavorable scenario unfolding.

The third tested strategic option is consolidation, which means a takeover of another steel asset. The strategy could bring benefits of the scale, learning curve, market power, access to new markets and technologies, synergy, etc. Consolidation is considered to be successful in scenarios 1 and 2 that means a bet on a favorable circumstance.

Poor performance of steel industry is observed through most parts of the conventional business cycle. It is reasonable to assume that desire to exit the steel business attends some shareholders of steel companies over and over again. The fourth, "exit the business strategy" seems to be a favorable option only in half of the scenarios (3, 4), so it could be also classified as a bet.

The fifth strategy is a nice exception. It looks reasonable to undergo semi-finished products additional treatment and to increase the share of the products with high added value in the

product mix. This move cannot be recommended only for vain hopes scenario, because the best behavior in this case is to exit steelmaking business. Thus, investing into high added value looks as the reasonable bet on three out of four scenarios.

Number	Strategic options	1. Super-cycle sunset	2. Steel bonanza	3. Vain hopes	4. Raw material is king	Strategy classification
1	Upstream integration	—	++	—	++	Bet
2	Supply contract	–	+	–	+	Flexible bet
3	Consolidation	+	++	–	–	Bet
4	Exit the business	–	—	++	+	Bet
5	Value-added products	+	+	–	+	Reasonable bet
6	Capacity ramp up	–	+	—	–	Risky bet
7	Industry cartelization	+	+	+	+	Robust initiative

Figure 8. Scenario assessment of the strategic option portfolio for the global steel industry[14]

The sixth strategy is building a new steelmaking capacity that seems to be a risky bet. It would be quite wise to expand capacity on the brink of a new gold decade for the steel industry.

However, acquiring an existing one could be more practical and less risky. For the rest three scenarios, building new capacities could not be recommended because of their surplus.

In spite of the fact that only one reasonable bet strategy was discovered, the combination of some other strategies could bring a similar result. For example, new raw material volumes that appear in the vertical integration strategy could be processed in additional capacities in case of consolidation or building greenfield. Consequently, combination of 1 and 3 or 2 and 6 options could bring favorable output in all scenarios apart from vain hopes.

The final, seventh strategy implies an organization of a cartel in the global steel industry for steel capacity control. It could harmonize supply-demand balance and support steel prices and margins. This option would benefit the steel industry in all scenarios and could be classified as a robust initiative. Low elasticity of steel demand to price change and absence of effective steel

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14) Adopted from Malanichev (2015)

substitutes support this possibility (Levenstein and Suslow 2006). However, this move is rather difficult to implement due to inherent instability of cartels because of a free rider problem, studied in the game theory as the Prisoner's Dilemma. (Jones 1986).

5.1 Steel market strategies in developing countries

The steel industry has seen its focus shift towards the emerging economies, as these require a huge amount of steel for urbanization and industrialization. This trend accelerated in the 2000s, with the rise of China and from 2011 onwards with emerging countries accounting for more than 70% of steel use and production – China now represents around 45%. This shift in momentum looks likely to continue with other developing economies, such as India and countries in Association of Southeast Asian Nations (ASEAN) and Middle East and North Africa (MENA).[27]

Steel plays important role in the developing countries because of its use in the infrastructural projects, transport and other fields. Furthermore the increase in the gross domestic product presupposes abundant use of energy and materials, structures etc.

Therefore, it is likely that the demand for steel and products made from steel will increase in the future. Consequently, steel producing companies has an opportunity to establish or further enhance trade or cooperation relationships with the government agencies or related private entities in terms of satisfying country, sectoral or firm-level steel demand.

Usually, developing countries are interested in the purchase of durable and high quality products. At the same time as a result of the 2015 COP21 Paris conference it seems that all countries agreed to be bound to make contribution in terms of GHG emission reduction by submitting their national targets. Therefore, from now on it is fairly reasonable to expect increasing demand for less energy consuming and GHG emitting materials, goods and structures.

5.1.1 Country case: Turkmenistan

Turkmenistan has gained its independence in 27 October 1991, after the collapse of the Soviet Union. Having almost no considerable heritage in terms of infrastructure and industrial capacity the country had to start its development from the very beginning. During the Soviet

period republic is used to serve as a raw materials source granting huge natural resources to the center almost free of charge. Therefore, main transformations have started after gaining independence in all of the sectors of the economy.
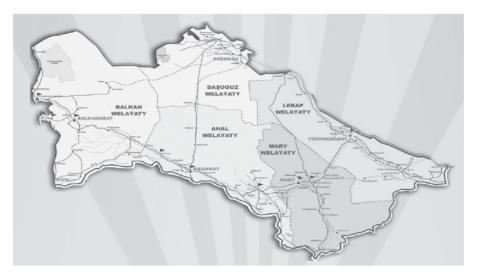

Figure 9. Map of Turkmenistan

A key objective of socio-economic policy in Turkmenistan is the creation of a favorable environment for sustainable social and economic development.

The Turkmen government carried out important reforms during 2008-2015 to obtain a greater balance and a stronger development in the economy. These reforms have done much to secure sustainable development in the post global recession period. A system of anti-crisis measures to minimize the impact of the global crisis on the country's socio-economic development has been developed and successfully implemented. These measures can be grouped as follows: (Author, 2013)

a) a high level of investment activity, directed at the diversification of the economy and increasing competitiveness, the creation of new businesses and jobs, and the expansion of domestic demand;

b) increased development of infrastructure;

c) fundamental measures to improve monetary and credit policy, strengthening of the

banking system, and efficient financial policy;

d) high rates of wage growth, measures to reinforce social guarantees;

e) ensuring availability of sufficient resources to support key economic processes.

The Turkmen economy has shown that it can maintain sustainable development even during the global crisis. The growth of GDP in 2013 was 10.3%[15] in comparable prices against 2012. This was mainly due to large investments in production facilities and in facilities with a social and cultural purpose, combined with strong growth of domestic consumption.

As we can see from the graph within 2007-2011 period GDP in current prices have tripled. Just in the 2011 the GDP increased by 14.3% compared to 2010.[16]

What about the structural component of the Turkmenistan gross domestic product? Here is the structural composition of the gross domestic product of Turkmenistan for the year 2011:
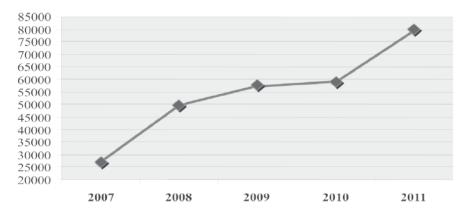
Figure 10. The Gross Domestic Product growth rate for the period of 2007-2011 (in current prices, mln.manat)

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[15] www.worldbank.org

[16] National Program for the socio-economic development of Turkmenistan for 2012-2016 years, Ministry of Economy and Development and Institute for strategic planning, Ashgabat, 2012
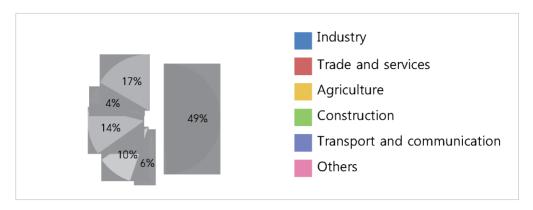
Figure 11. Structure of Turkmenistan Gross Domestic Product in 2011, %

It is noteworthy that almost half of the GDP structure composed of industry and the share of construction is also increasing steadily. Turkmenistan is well-known as one of the natural gas rich countries in the world. After the independence, oil processing, textile industries and manufacturing sector has been modernized by re-equipment with up-to-date technologies and processes. Currently, the infrastructure for chemical, construction materials, machinery and metallurgical sectors is strengthened continuously. (Author, 2013)

Therefore, Turkmenistan has a good potential to become big market for steel and steel products.

Regarding the cooperation between Turkmenistan and Korea Republic in the steel industry during the visit of the President of Turkmenistan Gurbanguly Berdimuhamedov to Korea on April 11-14 among signed package of intergovernmental documents was a memorandum of understanding between Industry Ministry of Turkmenistan and Daewoo International for the development of new projects in Turkmenistan's metallurgical industry.

In May 2009, the country opened the first metallurgical plant in the country. The plant was located in the area of Ashgabat and was built primarily to meet the needs of the construction industry. The construction of the plant was conducted by a consortium of Turkish companies and cost the country $64.5 million. The total capacity of the plant was 160,000 metric tons per year (t/yr), of which about 135,000 t/yr was expected to be produced from ferrous metals scrap, and the rest would be made from the imported ingots. The plant would produce rolled steel and rebar, as well as angle brackets and channel bars. The plant was expected to produce enough products to satisfy about 50% of domestic demand. (Safirova, 2015)

Turkmenistan has a wide variety of mineral deposits, but the most important from the economic perspective are its oil and gas resources. Turkmenistan's natural gas reserves are among the largest in the world and were estimated by different sources to be from 7 to 25 trillion cubic meters. Turkmenistan's oil reserves as of January 2012 were estimated to be 600 million barrels (Mbbl) according to Oil and Gas Journal. Most of Turkmenistan's oilfields are located in the west of the country in onshore areas near the Caspian Sea (U.S. Central Intelligence Agency, 2012; U.S. Department of State, 2012; U.S. Energy Information Administration, 2012). Among the nonfuel minerals produced in Turkmenistan are bentonite, bischofite, bromine, epsomite, gypsum, iodine, kaolin, lime, quartz sands, salt, sodium sulfate, and sulfur.

To sum up, in my opinion the following strategies can be followed by steelmaker companies on the way of cooperating with developing countries and Turkmenistan in particular:

1. Implementation of the pilot and demonstration projects related to the steel products, oil and gas equipment and others;

2. Questing for the possibility of establishment of Joint Venture Companies with the domestic enterprise involved in the production of steel or creation of it in order to organize the production process within the country so that to be in available in the near proximity to the market and demand respectively;

3. In order to increase profitability and be competitive, steelmaker needs to develop and deliver high-tech products. Another vital point is the development of relevant research base. At the same time there may be a need to teach the use of new products by going to the oil and gas fields and other project sites where the steelmaker's products are expected to be exploited.

4. Establishment of the oilfield services branch of the steelmaker company can be an option in delivering differentiated and innovative tubular and other products for the oil and gas industries. Now, to survive in the market, it is necessary not only supply of tubular products in the required quantities for a specific field keeping in mind its characteristics but also to produce accessories and downhole equipment. For instance, the consumer is not interested in receiving pipes only anymore, but rather a range of complementary services to the main product.

6. CONCLUSIONS AND RECOMMENDATIONS

As we have seen in the chapter related to the analysis of the current steel market, key factors surrounding the outlook include near stagnation in global steel demand, persistence of excess capacity as new investments continue to take place and low profitability for steelmaking companies. If we turn our look to the current global steel market then short-run outlook can be highlighted as follows: (Sekiguchi, 2015)

- Positive growth momentum is suggested by recent macroeconomic indicators regarding some economies. Although the world economy continues to face uncertainty, lower oil prices could boost economic growth particularly in oil importing economies.
- In accordance with forecasts we can observe deceleration in the global apparent steel use growth which accounted for only 0.6% in 2014 and expected to remain restrained at 0.5% in 2015, with only a limited recovery in 2016 of 1.4%.
- Modest output growth is expected to be registered by major steel-consuming industries in 2015 and 2016.
- Global steel intensity (the amount of steel used to produce one unit of GDP) is likely to decline during 2015-2016. In this context one of the most important drivers is being the decline of Chinese steel intensity.
- In response to weak market conditions, many steel producers are cutting production. At the same time, several crude steelmaking investment projects have been completed, and production has been started at these plants in recent months. Regions that are currently net importers of steel products are continuing to add new capacities.
- Prices of key raw materials have been declining and are likely to remain low amid weak steel demand.
- Steel prices have been decreasing together with excess steelmaking capacity and falling raw material prices. The recent drop in oil prices has affected steel prices, particularly in the segment of steel tubes and pipes. Weak earnings have led to a decline in the industry's profitability over the last few years, with little recovery expected in the near future.

Furthermore in accordance with the current trend, the introduction of high strength steel, aluminum, and composite materials is likely to reduce steel consumption from current 1000 to 830 kg/car in the next 10 years (Zeumer 2013).

As a result of the fact that steel industry usually deemed to be fundamental to the economy of every country the important steelmaker companies' long-term objectives are the increase of employment, the increase of value added by manufacturing, the emission reduction, the reduction of energy consumption in manufacturing and industrial production processes, environmental aspects, creating new jobs, enhancing the attractiveness of jobs in manufacturing and a challenge oriented research and development strategy. (Brummayer et al., 2015)

The global steel market seems to come to a new phase of its evolution characterized by chronic steelmaking overcapacity, China's economy slowdown, raw material price decline, and energy revolution in the USA. This complex and uncertain context casts a new view on the strategic options, some of which are traditionally applied in the global steel industry.

To maintain a leading position, innovative, efficient, eco-efficient and cost effective solutions must be implemented in the steel plants to enable them to stay ahead of competitors and to be prepared for economic changes and other influences in the years to come.

Innovation is a precondition to achieve sustainability in operational excellence. Introduction of green innovations is an especially important aspect of steel industry modernization.

Steel isn't just the material of our past. It will play an equally important role in our future.

The world's population is increasingly urban. In 2010, around half of us lived in towns or cities. By 2050, it will be around 70%. To handle this migration, cities are expanding rapidly to become mega-cities.

Building these mega-cities is going to take a lot of materials, not least of which is steel. Housing and construction already consume 50% of all steel produced. As urban population densities increase, so too does the need for steel to build skyscrapers and public-transport infrastructure.

The energy needs of emerging countries call for continuing exploration and production of hydrocarbons from conventional and nonconventional sources (shales) and from increasingly demanding environments. The steel industry is delivering the necessary hardware with environment friendly technologies.[17]

Integration and consolidation are ongoing processes in steel industry. Steelmakers from different countries have their own reasons for strengthening their standing in the global market.

Steelmakers from highly industrialized countries may seek to improve the structure of their upstream processing by using facilities located in developing countries. At the same time, local demand for quality steel will increase in emerging markets as automakers and home appliance manufacturers move their facilities to developing countries.

On the other hand, steelmakers in developing countries, while struggling to catch up with foreign steelmakers, must ultimately establish downstream facilities and distribution networks.

Global integration efforts will help reduce excess production capacity and strike a balance between supply and demand since an increase in manufacturing bases and markets allows large-scale steelmakers to scale their production capacity to demand.

In the future, global steel industry will likely divide itself into mass production markets and high-end markets controlled by a handful of steelmakers. The mass production market will grow in developing countries as international trade volume increases due to a surge in production facilities. Meanwhile, the stringent requirements of the high-end market, (including, for example, automotive and home appliances industries), will be met by steelmakers of highly industrialized countries, focused on enhancing) their upstream capacity in developing countries, and satisfying demand for short lead times by operating production facilities in local markets. (Kim, 2009)

It is evident that the steel industry and its players should strive towards creation of so called "resource circulating industry". While product stewardship tends to focus on resource recovery and recycling, reuse of steel offers the most potential among the '3Rs' (Reduce, Reuse and Recycle) for resource efficiency, as recognized by Stahel (1982). This concept is illustrated in Fig. 1. Loop 3 represents resource recovery as commonly practiced, whereby waste materials are intercepted before they become landfill and the materials are recycled back into themselves. Loop 2 represents the repair and remanufacturing process which, although reducing the demand for new raw materials, may still require a lot of energy. On the other hand, the inner loop 1 represents the reuse of goods e the 'cradle to cradle' idea e whereby the goods themselves circulate continually. When carried to its ultimate potential, they never go to waste and little

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17) A white book of steel, www.worldsteel.org;

energy consuming remanufacturing is required. As BlueScope Steel (2012) has acknowledged, 'reuse is the ultimate in recycling, no reprocessing energy is required; the component is simply moved from one location to another'.

The above technologies open up opportunities for new services and profit centres for steel companies. In addition to their core business focused on steel product manufacturing, they could enter the business of steel product recovery (reuse/recycle) and provide innovative information management services including life-cycle data. Furthermore, the company can develop life-cycle inventory databases and life-cycle management applications for steel products, and offer them as additional BIM Applications (BIM Apps) e such as 'Information-as-a-Service' and 'Application/Software-as- Service' - to architects, engineers and other clients. (Manzini and Vezzoli, 2003).
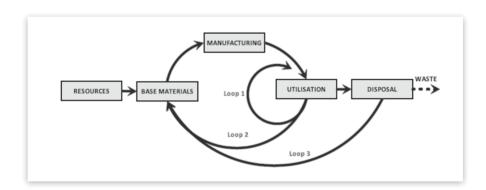

Figure 12. The reuse, remanufacturing and recycling loops.

Another promising area is the re-utilization of wastes from the steel production process such as slag and smaller quantities of other kinds of waste including dust, secondary metallurgy slag and refractories, and their safe disposal represents one of the major costs that the steelmakers have to face.

The exploitation and use of recycled waste by-products has manifold benefits, especially from the environmental point of view:

- reduction of the waste fraction sent to landfills;
- reduction of the exploitation of natural resources;

• reduction of activities impacting the territory (i.e. extraction and drilling);

• energy saving and reduction of CO_2 emissions.

There is a potential for the creation of comprehensive and process specific energy benchmarking system so that companies can submit data and compare their performance with a top 25% reference level for each process and determine what component in the process is deviating from the reference. This opportunity can be resorted to by the steelmaker companies in order to analyze their positioning in relation to the benchmarks.

Steel is a material which is 100% recyclable and can be reused indefinitely. This recyclability contributes significantly to the sustainability of steel, as the need for virgin resources is reduced significantly. Recycled steel also entails much lower energy consumption – manufacturing steel from recycled steel scrap requires about a third of the amount of energy needed to produce steel from the raw material of iron ore. Using recycled material is encouraged as much as possible across all regions. Scrap-based steel accounts for about 30% of the global steel production. However, due to the long life of steel products and the high demand for steel, today there is not enough available steel scrap to produce all steel from recycled material. The economics of recovering material is usually aligned with the price of raw materials, if they reduce in price they are used more and scrap prices drop as well, if scrap is scarce the prices increase.

The industry must continuously balance energy requirements and costs as well as the quantity of iron ore, coal, and scrap needed in order to minimize energy and by-products while providing the best quality material to suit the customers' demand.

The impact of urbanisation will have a key role to play in the future. It is estimated that a little more than 1 billion people will move to towns and cities between now and 2030. This major flow will create substantial new demand for steel to be used in infrastructure developments such as water, energy and mass transit systems as well as major construction and housing programmes.

Perhaps the most important impact steel can have is at the heart of the circular economy, which demands zero waste and reduced use of new materials as well as encouraging the reuse and recycling of materials – all fundamental advantages of using steel.

Input			Output		
Raw materials			**Products**		
Metallic input:			Liquid steel (LS)	kg	1000
Scrap	kg/t LS	1039-132			
Pig iron	kg/t LS	0-153	**Air emissions**		
Liquid hot metal[1]	kg/t LS		Off-gas flow	MNm^3/h Nm^3/t LS	1-2 8000-10000
DRI (HBI)	kg/t LS	0-215	Dust	g/t LS mg/m^3	4-300 0.35-52
Lime/dolomite[2]	kg/t LS	25-140	Hg	mg/t LS	2-200
Coal (including anthracite and coke)	kg/t LS	3-28	Pb	mg/t LS	75-2850
Graphite electrodes	kg/t LS	2-6	Cr	mg/t LS	12-2800
Refractory lining	kg/t LS	4-60	Ni	mg/t LS	3-2000
Alloys:			Zn	mg/t LS	200-24000
Carbon steel	kg/t LS	11-40	Cd	mg/t LS	1-148
High alloy and stainless steel	kg/t LS	23-363	Cu	mg/t LS	11-510
			HF	mg/t LS	0.04-15000
Gases			HCl	mg/t LS	800-35250
Oxygen	m^3/t LS	5-65	SO$_2$	g/t LS	5-210
Argon	m^3/t LS	0.3-1.45	NO$_x$	g/t LS	13-460
Nitrogen	m^3/t LS	0.8-12	CO	g/t LS	50-4500
Steam[3]	kg/t LS	33-360	CO$_2$	Kg/t LS	72-180
			TOC	g C/t LS	35-260
Energy			Benzene	mg/t LS	30-4400
Electricity	kWh/t LS MJ/t LS	404-748 1454-2693	Chlorobenzenes	mg/t LS	0.2-12
Fuels (natural gas and liquid fuels)	MJ/t LS	50-1500	PAH[4]	mg/t LS	9-970
			PCB[5]	mg/t LS	0.01-5
Water	m^3/t LS	1-42.8	PCDD/F	µg I-TEQ/t LS	0.04-6
			Production residues (waste/by-products)		
			Slag from furnace	kg/t LS	60-270
			Slag from ladle	kg/t LS	10-80
			Dusts	kg/t LS	10-30
			Waste refractories	kg/t LS	1.6-22.8
			Noise	dB (A)	90-133

[1] Hot metal is only used in very special cases (about 275 kg/t LS), then the quantity of scrap is lower
[2] Typically lime is used but in a few cases dolomite alone is used or combinations of dolomite and lime (e.g. weight proportion 63/37)
[3] Steam is generally not used within EAF steelmaking, except for plants with secondary metallurgy with vacuum treatment
[4] No consistent database, some results represent the total of 16 EPAPAH, other only a section of them
[5] No consistent database, values represent different selections of PCB (2 of them refer to the above-mentioned Ballschmiter PCB, 3 to WHO-TEQ and 2 without further indication).

NB:
- Some measuring methodologies might vary significantly from country to country ad from plant to plant. Not all the emitted substances are measured at all plants. The measuring programs vary greatly depending on permit requirements.
- Data has been compiled from information provided by EAF melt shop operators (carbon steel, alloy steel and stainless steel) representing 37.4 Mt of steel produced. This represented close to 50% of the total EAF steel production in the EU in 2004 in 11 different EU countries.
- LS = Liquid steel

Source: [140, Eurofer 2009] [200, Commision 2001] [220, Eurofer 2008] [234, Poland 2007] [367, Prum et al. 2005] [371, Eurofer 2007] [372, Czech TWG member 2008].

Figure 13. Input and output mass and energy flows for an electric arc furnace.

The test of strategic options on the scenarios by (Malanichev, 2015) allowed classifying them in different categories. Capacity ramp up, vertical integration, consolidation, and exit the business strategies appear to be rather risky bet or just bet options, because they deliver a favorable outcome only in one or two out of four scenarios. However, quasi integration with

supply contract seems to be a more flexible bet. On the contrary, value-added products development works well in three out of four scenarios and was classified as the reasonable bet. Finally, state-run steel industry cartelization could be a rather robust initiative to harness unreasonable investments in new steelmaking capacities and to stimulate the demolition of the obsolete ones. In general, it would be too bold to believe that one or another of the described scenarios will come true with the entire set of details elaborated in the course of this brief and superficial analysis. However, there are no concerns that some of the key factors forming the scenarios listed above would take place.

To sum up companies should adopt various strategies in the form of differentiation and leadership, to complement its direction and to service its stakeholders (esp. shareholders) with better paybacks and satisfaction.

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Prospects of Low Carbon Development in Nigeria Based on the LEAP Model

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Prospects of Low Carbon Development in Nigeria Based on the LEAP Model

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Abstract

The increasing trend of energy consumption and greenhouse gas (GHG) emissions has been an issue of global concern. This has increased the interest in energy planning in both developed and developing countries, as they channel their interest in developing a low carbon economy. This study presents a scenario analysis of future energy consumption and GHG emissions for Nigeria. The Long-range Energy Alternatives Planning system (LEAP) was used to stimulate a range of pathways and to analyze the impact of energy policies in the Nigerian energy system from 2010 to 2040. Four scenarios were developed and they include; a reference scenario (Ref), low carbon moderate scenario (LCM), low carbon advance scenario (LCA), and green optimistic scenario (GO). The implementation of various energy policies and strategies were increased from the LCM to the LCA, and more aggressively in the GO scenario. The results show that under the Ref scenario, energy demand is expected to reach 3,075 Petajoule (PJ) with a growth rate of 3.68%, with a corresponding increase in GHG emissions of 201.2 million metric tons of CO_2 equivalent (MMTCDE) by 2040. The more aggressive policy intervention in the GO scenario led to the decrease in energy demand (2,249 PJ) and GHG emissions (124.4 MMTCDE) in 2040. In terms of energy and GHG reduction, the household and transport sector are key area for low carbon development in Nigeria under the LCA and GO scenario, while the

industry and commercial/service sectors also holds great potential in the reduction of energy consumption and GHG emissions in the coming years.

1. Introduction

During the last century, the world experienced a transition in energy use from coal based to petroleum based. Due to the increase in globalization and industrialization, the global demand for energy has increased exponentially [1]. With the increase in demand for energy, its production has also increased such that about 80% of global energy supply comes from fossil fuel [2]. The increase in the reliance on fossil fuel has resulted in an increase in global greenhouse gas emissions and this has raised issues about the sustainability of the environment due to problems such as climate change and depletion of resources [3].

Energy consumption has been one of the most reliable indicators of the development and quality of life reached by a country, and the necessity of satisfying a forecasted energy demand for a given period of time is rationale for energy planning [4]. As defined by the World Energy Council, "Energy planning is that part of economics applied to energy problems, taking into account the analysis of energy supply and demand, as well as implementation of the means for ensuring coverage of energy needs in a national or international context" [5]. Researchers around the world have employed different energy models to address policy and planning concerns of energy, economy and the environment [6].

1.1 Background of the Problem

In many developing countries mostly in Africa and some in Southeast Asia, access to clean energy is known to be unreliable and at high disruption costs which affects production efficiency and competiveness [7]. Being endowed with the widest possible range of energy resources, the African continent has experienced a relatively low energy consumption in general and electricity consumption in particular [8]. Nigeria is experiencing a remarkable paradox – the abundance of energy resources and widespread energy poverty with about 40% of the population having

access to the grid electricity supply, while 70% depends on firewood [9]. This dependence on firewood constitutes a major indoor pollution hazard and has caused the death of about 79,000 Nigerians due to smoke inhalation from 2011 [10]. According to a study by the World Health Organization in 2013, the deaths caused by smoke inhalation from fire wood use by women reached 98,000 [11].

The Nigerian Government action to address the issue of energy poverty, has been through the increased amount of gas power plants for electricity generation [12], while plans are still in progress to introduce other sources of energy services. The plans are being set up by the government agency, the Energy Commission of Nigeria (ECN) which is responsible for the strategic planning and coordination of national policies in the field of energy in all its various forms in Nigeria [13]. The ECN carried out a study to ascertain the projected future energy demand and supply under some scenarios. This study was carried out using the Model for the Energy Supply Strategy Alternatives and their general Environmental Impact (MESSAGE) and the results are included in the current National Energy Master Plan [14].

1.2 Statement of the Problem

- **The study carried out by the ECN did not develop scenarios considering various parameters which can influence energy demand.** The only parameter considered was economic growth rate (GDP) which is not the only determinant for the increase in energy demand. Other parameters include; population, income, household size, technology, energy prices etc. Also, least cost options were not observed in the ECN study.

- **The impact of future energy policy implementation and strategies were not considered in the ECN study.** The impact of various energy policies is expected to alter the energy consumption pattern of a country on the short-, medium-, and long term. Also incentives such as Feed-in-Tariff may also affect energy consumption pattern.

- **The effect of greenhouse gases on the environment were not taken into account in the ECN study.** The contribution of GHGs to climate change cannot be left out when carrying out energy modelling because this have a direct impact on the society. The effect of climate change can be observed in almost all part of Nigeria and as such, the consideration for GHGs reduction is important.

1.3 Research Question

There are two research question this research presents and they were derived from the research problems and they are;

i. What are the projected energy demands in Nigeria and how can the demands be met at a least cost without a similar expansion in GHGs?

ii. Which sustainable energy policy options are recommended to ensure a low carbon development is realized in Nigeria?

1.4 Research Goal

This study aims to answer the research questions by using the Long-Range Energy Alternatives Planning system (LEAP). It is anticipated that this investigation will present an opportunity for Nigeria to select from a variety of renewable energy options, low-carbon technologies and energy efficiency tools to moderate growth in energy demand. This study also intends to provide vital energy policy recommendations for the Nigerian government and energy policy experts to strengthen planning for the future energy systems in Nigeria. This study however does not take into account the ability of consumers to pay for energy services or explore the effect of energy pricing. The scope of this study lies within the range of projected energy demand and supply, and its accompanying GHGs reductions, while briefly projecting the social cost of each policy scenario in the Nigerian LEAP model.

The rest of the paper is organized as follows. The next chapter presents the methodology used in this study which includes the model, formulates the policy scenarios and describes the data used and their source. Chapter 3 presents the results and discussion of the scenarios developed. Chapter 4 concludes the paper with some policy implications.

2. Methodology, Data and Scenario Development

2.1 The Model

The Long-range Energy Alternatives Planning system [15] (LEAP) is a scenario-based

energy analysis and climate change assessment modeling tool, developed by Stockholm Environment Institute [16]. The LEAP develops different scenarios of projected energy demand and environmental impact based on how energy is consumed, converted, and produced in a given region or economy under a range of values for parameters such as population increase, economic development, technology utilization and inflation [17]. With a flexible data structure, LEAP is user-friendly and rich in technical specifications and end-use details [18]. The model has been extensively used at the local, national, and global scales to project energy supply and demand, predict environmental impact of energy policies, and identify potential problem.

The LEAP model has been used for policy scenario assessment of energy consumption and CO2 emission from the industrial, transport and building sectors on a global scale [19]. On a national scale, the LEAP has been applied to ascertain the projected direct energy consumption in Nigerian households [20], while other researchers investigated the emissions reduction potential and mitigation opportunities in China's five major emission sectors [17]. At the local level, it was used to model total energy consumption and associated emissions from the household [21] and transport [22] sectors of Delhi, India. The LEAP was also used to study the energy and environmental impacts of the transport sector having been researched through the application of the LEAP model by Dhakal [23] and Pradhan et al. [24]. LEAP has also been used to project the future electricity generation mix and some studies were carried out by Zhang et al. [25] and Shin et al. [25]. On biomass, Bala [27] projected the rural demand and supply and assessed the contributions to global warming from biomass for Bangladesh, while biomass energy utilization has been carried out by Kumar et al. [28]. Researchers have used LEAP to evaluate the efficiency of city level policies aimed at reducing energy demand and GHG emissions in the urban sector [29-32]. However, the only bottom-up study that comprehensively investigated the impact of energy policies in the Nigerian household was carried out by Ibitoye [20]. Thus, no other study has applied a bottom-up approach to ascertain the impact of energy policies in the future energy system in Nigeria.

2.2 The Algorithm of the LEAP model

The LEAP uses a framework for calculating energy consumption, transformation (Electricity generation, oil refinery, charcoal production, coal mining), and carbon emissions and this are

presented as follows.

2.2.1 Energy consumption

The total final energy consumption is calculated as follows [33]:

$$EC_n = \sum_i \sum_j AL_{n,j,i} \times EI_{n,j,i}$$

Where EC is the aggregate energy consumption of a given sector, AL is the activity level, EI is the energy intensity, n is the fuel type, i is the sector, and j is the device.

The net energy consumption for transformation is calculated as follows:

$$ET_s = \sum_m \sum_t ETP_{t,m} \times \left(\frac{1}{f_{t,m,s}} - 1 \right)$$

Where ET is the net energy consumption for transformation, ETP is the energy transformation product, f is the energy transformation efficiency, s is the type of primary energy, m is the equipment, and t is the type of secondary energy.

The transport stock turnover is calculated as follows:

$$EV_n = \sum_c s \times \frac{m}{fe}$$

Where EV is the energy consumption in the transport sector, s is the number of vehicles (stock), m is the vehicle distance, fe is the fuel economy, n is the fuel type, and c is the vehicle type.

2.2.2 Transformation

The transmission and distribution module calculations take the domestic fuel requirement

faced by the module and map those corresponds to the output fuels directly to the module input fuels. The total domestic requirements are then decreased by the outputs of the module and increased by the inputs to the module [34]:

For each process p:

$$INPUT_P = \frac{OUTPUT_P}{EFFICIENCY_P}$$

For a Transmission and Distribution module:

$$EFFICIENCY_P = 1 - LOSSES_P$$

Where INPUT is the fuel or feedstock, OUTPUT is the electricity generated or the refinery/production output, EFFICIENCY is the efficiency of the power plants or refinery plants.

2.2.3 Carbon emission

The carbon emission from final energy consumption is calculated as follows (Feng and Zhang, 2012):

$$CEC = \sum_i \sum_j \sum_n AL_{n,j,i} \times EI_{n,j,i} \times EF_{n,j,i}$$

Where CEC is the carbon emission, AL is the activity level, EI is the energy intensity, and is the carbon emission factor from fuel type n for equipment j from sector i.

The carbon emission from energy transformation is calculated as follows:

$$CET = \sum_s \sum_m \sum_t ETP_{t,m} \times \frac{1}{f_{t,m,s}} \times EF_{t,m,s}$$

Where CET is the carbon emission, ETP is the energy transformation product, f is the energy

transformation efficiency, and   is the emission factor from one unit of primary fuel type s consumed for producing secondary fuel type t through equipment m.

2.2.4 Costs

The total cost of sector is calculated as follows [35];

$$c = \sum_i \sum_j \left\{ \left[\sum_n (e_{n,j,k} e p_n) + \sum_k (m_{k,j,i} m p_k) + f c_{j,i} \right] p_{j,i} \right\}$$

Where C is the total cost of sector including equipment fixed costs and variable costs for raw materials and fuels, ep_n is the unit price of fuel type n, $mk_{j,i}$ is the demand for raw material k per unit of production used in equipment j within production process i, mp_k is the unit price of raw material k, and $fc_{j,i}$ is the fixed cost per unit production through equipment j (within production process i).

2.3 Scenario Development and Assumptions

The scenarios to be formulated are based on the Nigerian government's planned expansion of electricity capacity, energy services and proposed mitigation options for the Reference scenario (Ref). Much of the formulation in the Ref scenarios are available in the National Energy Master Plan [13]. This research used the Ref scenario as a benchmark for the development of three alternative scenarios which are; Low Carbon Moderate (LCM), Low Carbon Advance (LCA) and Green Optimistic (GO). The Ref scenario represent the base case without any energy policy intervention. The alternative scenarios on the other hand had its policy strategies increased from the LCM with moderate policies, to a more aggressive LCA scenario, and the GO scenario which has a high level of renewable energy application at both the demand and supply side. The summary of the key assumption parameters and features of each scenario used in the Nigerian LEAP model are presented in Table 1 and Table 2.

The Nigerian LEAP model is divided into two main branch (see Figure 1), the demand and supply branch. The demand branch is made up of households, industry, commercial /services, agriculture and transport sector. The household is further divided into urban and rural

households which represents the current household situation in Nigeria. The households includes various household appliances that is common in Nigerian households. The rural and urban households were further divided into electrified and non-electrified as stipulated by the National Bureau of Statistics. The transport sector was also classified into 6 (six) vehicle categories which include; motorcycles, cars, light goods and heavy goods vehicles, urban bus and long distance coach. On the supply branch, the transformation sector was divided into transmission and distribution (for electricity and natural gas), electricity generation, charcoal production, oil refining and coal mining. The resources branch under the transformation sector includes primary and secondary resources.

Figure 1. The Nigerian LEAP Model branches

Table 1. Key assumption parameters for the Nigerian LEAP model under the Ref, LCM, LCA, and GO Scenarios

Key assumption	Ref**		LCMS		LCAS		GOS	
	2010	2040	2010	2040	2010	2040	2010	2040
GDP (million USD)	369	1255*	369	1476*	369	1587*	369	2177*
GDP growth rate (%)	8		10		11		13	
Income (Thousand USD)	2310	5705	2310	5914	2310	6329	2310	6676
Income growth rate (%)	4.9		5.2		5.8		6.3	
Population (Million)	160	304	160	318	160	328	160	337
Population growth rate (%)	2.55	3	2.55	3.30	2.55	2.40	2.55	3.70
Households (Million)	37	72	37	80	37	84	37	87
Household size (people)	5							
Household growth rate (%)	3.16		3.9		4.2		4.5	
Urbanization rate (%)	44	70	44	75	44	80	44	73
Industry growth rate (%)	6	6.5	6	7.1	6	7.5	6	7.7
Commercial/ Services growth rate (%)	12	12.5	12	13.2	12	13.6	12	13.9
Agriculture growth rate (%)	6	6.5	6	7.3	6	7.4	6	7.8

*denotes Billion, **the figures in the Ref scenario are based on the NEMP 2014.

Table 2. Summary of the features in each Scenario

	Ref	LCM	LCA	GO
Driving philosophy	Follows the Government's most-likely-developmental-pathways for the energy system	Driven by cheaper capital, cost, readily available fuels to improve power supply, and moderately reduce energy demand	Motivated by a cleaner fossil fuel power technologies and an aggressive reduction in energy demand	Based on a low-carbon-green growth economy in view of mitigating global climate change, reduce energy poverty, and ensure energy sustainability.
Scenario characteristic	• Current trend of energy consumption continues in all sectors • No supply side diversification of energy source (BAU case)	• Moderate improvement in energy efficiency in all sectors • CFL bulbs to replace 70% incandescent bulbs • Increase in gas power plants, small share of renewables • Introduction biofuel in transport sector • Moderate reduction in electricity T&D and natural gas loss	• Aggressive improvement in energy efficiency in all sectors • LED bulbs to replace 70% incandescent bulbs • Increased capacity of efficient low carbon fossil fuel power plants, increased share of renewables • Introduction of LPG fuel options in addition to biofuel to complement conventional fuels in the transport sector • Improved reduction in electrical and natural gas losses	• Provision of Energy efficiency and solar PV systems for the demand side • Phase-out incandescent bulbs and replace with CFL 60% & LED 40% • Reduction in the share of fossil fuel plant capacity and the increase share of renewables on the supply side • CNG, LPG and biofuel options with a reduced share of conventional fuels • Reduction in electrical and natural gas losses to the barest minimum
General assumptions	Increased electricity access to 100% by 2030			

Scenario-specific assumptions	Demand side: Business-as-usual case in all sectors Supply side: Installed capacity by 2040 = 155283 MW Estimated share of fuel type: Fossil fuel = 90% Renewables = 10%	Demand side: CFL introduction, moderate energy efficiency in appliances Supply side: Installed capacity by 2040 = 170500 MW Estimated share of fuel type: Fossil fuel = 80% Renewables = 20%	Demand side: LED introduction, aggressive energy efficiency in all sectors Supply side: Installed capacity by 2040 = 180500 MW Estimated share of fuel type: Fossil fuel = 60% Renewables = 40%	Demand side: introduction of both CFL and LED with reduction in incandescent bulbs, advance approach towards energy efficiency in all sectors Supply side: Installed capacity by 2040 = 181000 MW Estimated share of fuel type: Fossil fuel = 30% Renewables = 70%

2.4 Data Source

The required data and their various sources are presented in Table 3 below;

Table 3. Data source

Data	Source
GDP, GDP per capita, GDP growth rate, Population, Population growth rate, Urban and Rural population/percent, Industry and transport value added	The World Bank Development Indicators. www.worldbank.org
Projected population growth	National Population Commission, National Bureau of Statistics
Household size and Characteristics	National Bureau of Statistics. http://www.nigerianstat.gov.ng
Agriculture and commercial sector	
Industry and transport sector energy consumption	IEA (International Energy Agency). 2011. World Energy Outlook 2011. Paris: IEA.
Industrial electricity and household supply	International Energy Agency, Central Bank of Nigeria Statistical Bulletin
Transport sector characteristics	Nigeria Vision 2020 National Technical Working Group on Transport
Electricity sector characteristics (generation, transmission, capacity factor, historical production)	National Control Center Osogbo Generation and Transmission Grid Operation Annual Technical Report 2010, Federal Government of Nigeria Roadmap for Power Sector Reform 2010,
Government energy/electricity demand and supply projection.	National Energy Policy (2014), National Energy Master Plan (2014)
Emission factors	IPCC guidelines for national GHG inventories
Government renewable energy and energy efficiency plan	Draft National Renewable Energy and Energy Efficiency Policy (2014).
Greenhouse gas emissions from energy consumption and electricity generation	2006 IPCC guidelines for national GHG inventories

As shown in Table 3, most of the data used in the scenario development were based on government documents, while the alternative scenarios were based on assumptions of the best possible approach to a low carbon development in Nigeria.

3. Results and Discussion

3.1 Results

3.1.1 Energy Consumption

Based on the assumptions about the socio-economic development in Nigeria and various parameters presented in Table 1 and Table 2, the values of total energy consumption the Nigerian LEAP model for the Ref, LCM, LCA, and GO scenario from 2010 to 2040 are shown in Figure 2. In general, energy consumption will increase steadily up to 2040 under each scenario, but with different growth rates. The energy consumption in the Ref scenario is expected to reach 3,075 Petajoule (henceforth, PJ) by 2040, from 1,039 PJ in 2010, with an annual growth rate of 3.68%, the highest amongst the four scenarios. Much of the energy consumed in the Ref scenario in the base year comes from the household sector with a share of 40%, which is followed by the industry (29%), and transport (22%). This however, made a slight shift in 2040 with an increase in the household and commercial/service sector which saw the reduction in industry and transport sector.
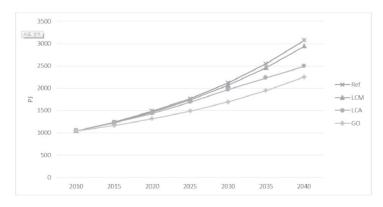
Figure 2. Energy consumption under the four scenarios from 2010 to 2040

Due to the series of energy efficiency improvement, fuel and technology switching, the total energy consumption will be lower under the alternative scenarios. The LCM scenario energy consumption is reduced to 2,941 PJ with an annual growth rate of 3.53%. As can be recalled from Table 2, the moderate improvement in the demand sector were energy efficiency measures such as the replacement of 70% incandescent bulbs with CFL bulbs. The more aggressive energy policies in the LCA scenario led to the decrees in energy consumption to 2,488 PJ at a growth rate of 2.95%. The household sector saw its share reduced, while the transport sector share of energy consumption increased, and this is due to the introduction of LPG for the transport sector (Figure 3).
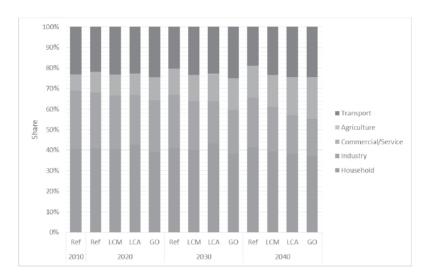
Figure 3. Proportion of energy use by sector

The GO scenario which has a higher level of renewable energy application such as solar PV and efficient use of firewood for the household had a reduced total energy consumption of 2,249 PJ at a growth rate of 2.61%. As observed in Figure 3, the household had a slight reduction in energy consumption as compared to the LCA scenario, which is due to the phase-out of incandescent bulbs, efficient bulbs and the provision of solar PV to reduce energy demand.

3.1.2 Final Energy Use by Fuel

The structural changes in the final energy usage in 2020, 2030, and 2040 is shown in Figure 4 for the four policy scenarios. It is apparent that under the Ref scenario, the energy usage structure will remain almost the same as that in 2010, with a slight increase in electricity consumption to 19%. Biomass, kerosene and gasoline will still dominate the Nigerian energy consumption system by 2040 under the Ref scenario. In contrast, under the alternative scenario, the proportion of kerosene consumption will decrease to 23% in the LCM, 21% in the LCA, and 20% in the GO scenario. The decrease of kerosene use in the alternative scenario is seen as a result of the energy efficiency improvement in cooking technology (efficient kerosene cooking stoves) and provision of alternative fuel options.
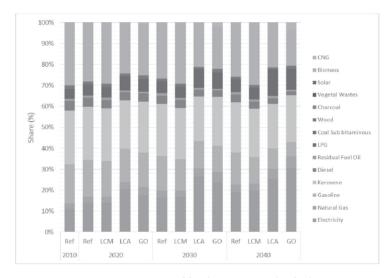
Figure 4. Proportion of final energy use by fuel

The share of gasoline decreased in the alternative scenarios from LCM (11%) to LCA (10%), while the GO had 9% gasoline use which is due to the increase popularity of CNG (4%) and LPG (10%) as an alternative fuel options for the transport sector. Moreover, the share of clean energy usage, including electricity, LPG, CNG (in the GO) and natural gas will increase rapidly across the alternative scenarios, contributing more than 50% by 2040. Overall, under the LCA and GO scenario, the energy usage structure will gradually become environmentally friendly in Nigeria, with rapid growth in alternative clean energy. This will play an important

role in the realization of a low carbon development in Nigeria and GHG mitigation as discussed in Section 3.4.

3.1.3 Electricity Generation

In order to meet the growing demand for electricity, the Ref scenario assumes an expansion in electricity generation capacity to be able to generate 179,000 MWh by 2040 as shown in Figure 5. The electricity mix under the Nigerian government Ref scenario by 2040 will include 36% of power generation coming from single cycle gas turbine (SCGT) and 18% from combine cycle gas turbine (CCGT) for on-grid electricity supply, while 18% will be generated from off-grid diesel generators. The contribution of renewable energy technologies is low when compared to the alternative scenarios, especially the LCA and GO scenarios.
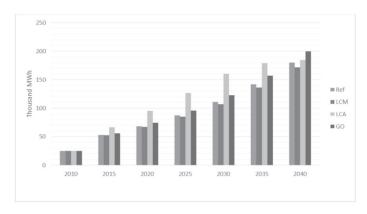
Figure 5. Electricity supply projection to 2040 under the four scenarios

The LCA scenario had an electricity supply of 184,000 MWh from the combination of power plants which comprises of 60% fossil fuel and 40% renewables by 2040. The reduction in the amount of SCGT power plants (7%), while increasing CCGT share will contribute to improved efficiency of gas power plants, since CCGT is more efficient than SCGT. Other fossil fuel power plants with less emission includes coal integrated gasification combine cycle (IGCC) and circulating fluidized bed (CFB), with the share of 8% and 9% respectively (Figure 6).
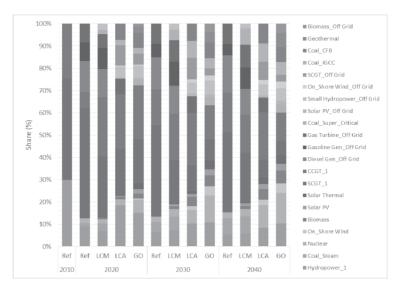
Figure 6. Share of electricity generation mix by 2040 under the four scenarios

However, visible presence of renewables will include large hydropower (9%), biomass (5%), on-shore wind (2%), solar thermal and PV system at 2% each for on-grid power supply as shown in Figure 6. The mix is further improved with an increase share of renewable power generation of about 70% in the GO scenario. This was intended to increase electricity generation from clean and sustainable source, while reducing GHG emission level by 2040.

3.1.4 Greenhouse Gas Emission

The GHG emission from energy consumption under the four scenarios from 2010 to 2040 is shown in Figure 7. Under the Ref scenario, GHG emissions will increase from 50.2 million metric tons of CO_2 equivalent (henceforth, MMTCDE) in 2010, to 201.2 MMTCDE in 2040 with an annual growth rate of 4.74%. The rate of GHG emission can be correlated directly to the level of energy consumption as observed in the Ref scenario (compared with Figure 2) and the same case holds for the LCM at 185.4 MMTCDE. Under the LCA, emissions will increase to 152 MMTCDE in 2040 at a significantly growth rate of 3.87%, which is in line with the total energy consumption trend predicted for the LCA in Figure 2. However, under the GO scenario, the emission will reach a peak value of 124.4 MMTCDE in 2040.
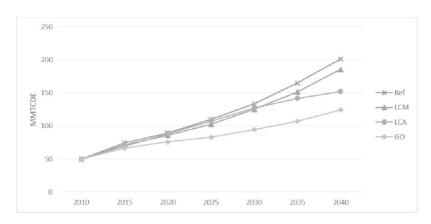
Figure 7. GHG emissions under the four scenarios from 2010 to 2040

The turning point in the GHG emission pathways in the LCA from 2030 is probably due to the optimization of the energy structure. Furthermore, energy intensive sectors such as the iron and steel industries in the GO scenario will experience technology switching[1], while electricity usage will be increased in all sector to reduce fossil fuel consumption[2]. On the supply-side, the increased use of renewable in the GO scenario also contributed to the reduction in GHG emissions as this can be observed in Figure 6. This entails that in order to achieve a low carbon development in Nigeria, the introduction and deployment of clean energy technologies should not only focus on the demand alone, but also the supply.

3.1.5 Social Costs

For the sake of this study, social cost is defined as the expense to an entire society resulting from a change in policy[3] or the total cost to a society which includes both private costs and external costs. The social costs for each scenario as shown in Figure 8 includes the environmental externalities costs which is the external costs, the fuel production, transformation variable operation and maintenance (O&M), transformation fixed O&M, transformation[4] capital,

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[1] This will be the switching to electric arc from conventional blast furnace and other efficiency improvement in the industrial sector.

[2] Kerosene, firewood, charcoal and biomass consumption is expected to reduce in the demand sector, since the electricity supply will be increased and the use of electricity for cooking and lighting will be encouraged.

[3] http://www.businessdictionary.com/definition/social-cost.html

demand[5] and avoided vs. reference[6] scenario costs which all fall under the private costs. Transformation module was insignificant because the cost of refinery were not included the Nigeria LEAP model, and the cost of unmet fuel requirement was removed because all power plant in the supply sector and fuel requirement in the demand sector were assumed to be met in the model.
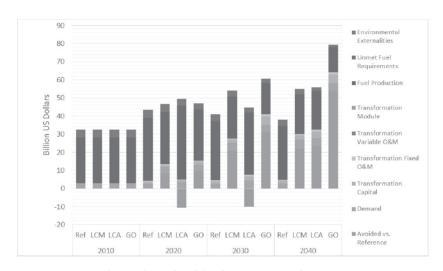

Figure 8. Social costs benefit of the four scenarios from 2010 to 2040

From Figure 8, it's observed that the environmental externalities cost decreased across scenarios from 2010 to 2040, with the lowest in the GO scenario (1.6 billion US$). This cost was higher in the LCA (2 billion US$) and LCM (3 billion US$), and this shows the impact of the various energy policies and strategies proposed in Table 2. The inclusion of more renewables in the GO proved that environmental externality cost will be greatly reduced if the Nigerian government invest more in clean energy technologies. The cost of fuel production is higher in the LCM and LCA, as compared to the GO scenario. The cost which is the difference between the alternative scenario (i.e. LCM and LCA) refers to the cost for fossil fuel production which

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[4] All the transformation costs were calculated from the supply side, which is the electricity generation sector.
[5] The demand costs is the costs paid by the demand sector of the Nigerian economy which includes the households, industry, commercial/services, agriculture and transport sectors.
[6] This simply means the cost of avoiding the situation in the Ref scenario. If this is positive, then it is a cost to Nigeria, but if negative, then it's a benefit to Nigeria as well.

includes nuclear fuel (uranium), natural gas, coal etc. In the case of the GO, fuel production costs is lower due to the shift to renewable energy resources in both the demand and supply-side. Although the LCA employed renewables in the energy mix, the share of fossil fuel energy technologies was high and led to the increased cost of fuel production (21.2 billion US$ by 2040).

For electricity generation (transformation), the capital and fixed O&M cost will be higher if Nigeria move towards a low carbon economy due to the high cost of renewables at 5% discount rate. The demand sector in the GO scenario will pay a lower cost for energy consumption (4.5 billion US$) than the LCA (4.6 billion US$) and LCM (4.9 billion US$) by 2040. This is in line with the reduced cost of fuel production which is lower in the GO scenario as the demand sector in Nigeria will require less fossil fuel demand as compared to other alternative scenarios. As expected, the cost of avoiding the Ref scenario is supposed to be high as it will cost Nigeria 22.1 billion US$ in the LCM, 23.3 billion US$ in the LCA, and 53.6 billion US$ in the GO scenario by 2040. However, Nigeria will gain benefit in the LCA from 2020 (10.5 billion US$) to 2030 (10 billion US$). This benefit will be realized in the supply and demand sector as the replacement of efficient energy technologies will led to the reduction in energy demand. In general, the cost in the GO scenario is higher than other alternative scenarios, but the government and policy makers should focus more on the societal benefit that can be achieved when investing in clean energy technologies.

3.1.6 Energy System

Notably, with the accelerated population, urbanization and improvement of living standards in Nigeria, the energy consumption in the household, industry, commercial/service, and transport sector is predicted to increase greatly in the future. This will directly affect the total energy consumption and energy system in the future from 2010 as shown in Figure 9, to the four scenarios as shown in Figure 10 (Ref), Figure 11 (LCM), Figure 12 (LCA), and Figure 13 (GO).
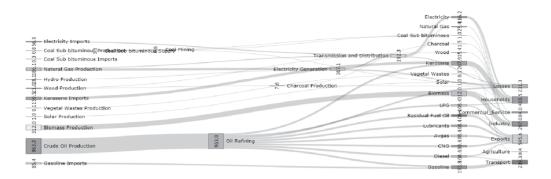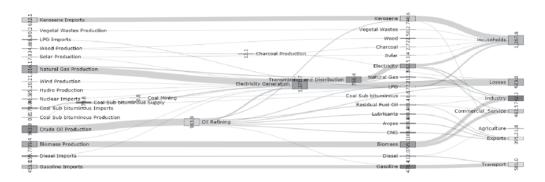
Figure 9. Nigeria energy system in 2010

Figure 10. Nigeria energy system in 2040 under the Ref scenario
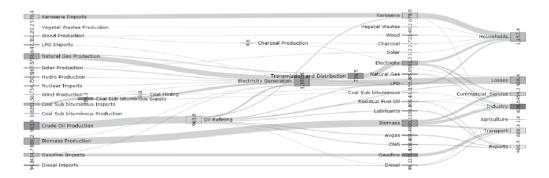

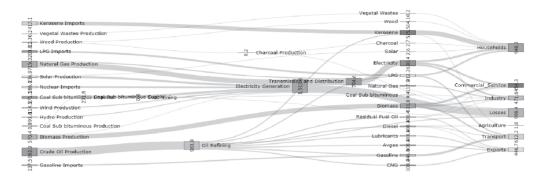Figure 11. Nigeria energy system in 2040 under the LCM scenario

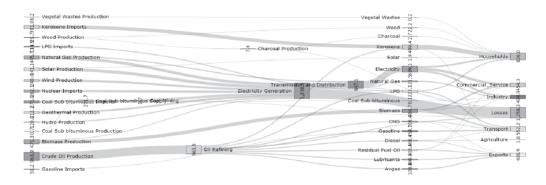Figure 12. Nigeria energy system in 2040 under the LCA scenario

Figure 13. Nigeria energy system in 2040 under the GO scenario

The observed changes showed that as various alternative fuels becomes popular and acceptable in Nigeria, the refinery capacity in Nigeria which currently stands at a total of 445,000 barrels per day (bbl/d) will not be sufficient enough to meet the growing energy demand. This implies that natural gas products such as LPG of 114.9 PJ will have to be imported to support the low refinery capacity in Nigeria for the GO scenario, while CNG will be refined locally to meet the transport demand of 28.4 PJ.

Crude oil product import such as gasoline (453 PJ) is expected to decrease across the alternative scenarios as more alternative fuel options such as biofuel (in LCM), LPG (in LCA), and CNG (in GO) becomes commercially available. The same goes for kerosene import in the Ref (632.1 PJ), which decreased across scenario, and had the lowest import in the GO (391 PJ). The increased use of improved stoves for charcoal, firewood and other biomass produce will not only complement kerosene use, but also ensure the efficient utilization of Nigeria's energy

resources with a reduced GHG emissions. On the supply side, the import of nuclear fuel will increase from the Ref scenario (46.5 PJ), to the LCA (186 PJ) and GO (262.1 PJ) by 2040, which is correlated with the power plants shown in Figure 6. The energy system in general under the alternative scenarios show great potentials for the reduction of GHG emissions under various level of policy implementations in each scenario. The "bottle-neck' will be the availability of funds for the implementations of the proposed policies and strategies, and the solution to this will be discussed in subsequent sections.

3.2 Discussion

As a signatory to the UNFCCC and Kyoto Protocol, Nigeria will have to make international commitments in promoting Low-Carbon development by meeting its reporting obligation to the UNFCCC, reducing greenhouse gases (GHG) emissions within the context of poverty reduction and economic growth [49]. Among the four policy scenarios, the alternative scenarios will achieve some improvement in energy and GHG reduction. Under the LCA and GO scenario, the emission will be 7% and 11% lower than the Ref scenario by the end of 2040. Obviously, the GO scenario shows a more favorable development trajectory towards a low-carbon development for Nigeria, demonstrating that more carbon emission reduction are possible by implementing additional policies and strategies. Thus, specific measures can be recommended for certain sectors of Nigeria's economy to achieve and sustain a low-carbon development.

For the households or residential sector, the emphasis should be on improving the efficiency of energy technologies such as kerosene, charcoal, and firewood cooking stoves. The ECN stressed the need for the massive deployment of these efficient cooking stoves for the Nigerian households in its national energy policies, but efforts to popularize the energy technologies have been slow. To complement this, LPG and solar cooker should be introduced into the household energy mix. Agbo and Oparaku [50] highlighted some pressing policy issue preventing the deployment of these energy technologies and alternative fuels to be poor research and development (R&D), pilot and demonstration projects, institutional framework, investment promotion, incentives and protections.

However, if the Nigerian government intends to achieve a reduction in energy demand and GHG emission as observed in the LCA and GO scenario, this challenges need to be addressed.

74

On improving the efficiency of household electrical appliances, emphases should be on implementing energy standards of refrigerators, air conditioners, electric stoves and more importantly, phasing out incandescent bulbs and replacing them with LED and CFL bulbs.

Some measures such as the "Phase out Incandescent Light Bulbs (POILB)" should be employed[7]. This measure comes as a kind of regulations effectively banning the manufacture, importation and sale of incandescent light bulbs to the public[8]. Most countries around the world have employed this policy measures and they include, China who started the ban in 2012, but extended it to 2016[9], India also started the ban on incandescent bulbs in 2012[10], Israel phased it out since 2012[11], the United Kingdom in 2011[12], and all European Union (EU) countries have until 2016 to completely phase out incandescent before 2016[13]. Other countries include Canada who made a move in 2007[14], while most states in the United States (US) have completely phased out incandescent since 2007 and others will be in 2018[15]. Some countries implemented new energy standards and phase out incandescent bulbs, among them include Argentina in 2012[16], Mexico, Malaysia and South Korea[17] in 2014. The Nigerian government can also stimulate the residential sector to improve household efficiency through the provision of subsidies for consumers who purchase and use efficient appliances, as well as renewables such as solar thermal and PV systems.

For the commercial/ service sector, the status quo on the households sector also holds for electrical appliances and lighting bulbs. Furthermore, the provision of adequate electricity supply will ensure the proper shift towards the use of electricity as a final energy consumption, instead of fossil fuel such as diesel, gasoline, biomass etc. The same stimulus policy for

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[7] See www.energyrating.gov.au/products-themes/lighting/lighting-and-phase-out-general-information/
incandescent-light-bulbs-phase-out/

[8] www.lampochki.org.ua/en/topovaja-novost-4/

[9] www.reuters.com/article/2011/11/05/us-china-light-bulbs-idUSTRE7A40MV20111105

[10] www.treehugger.com/interior-design/india-to-phase-out-400-million-incandescent-lightbulbs-by-2012-
replace-with-cfls.html

[11] www.energy.gov.il/LightBulb/Pages/GxmsMniMiniSiteLightBulb.htm

[12] www.news.bbc.co.uk/2/hi/uk_news/7016020.stm

[13] www.greenpeace.org.uk/blog/climate/eu-ban-inefficient-light-bulbs-eventually-sort-20081212

[14] www.reuters.com/article/2007/04/25/us-lightbulbs-env-idUSN2529253520070425

[15] www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1109_bill_20070223_introduced.html

[16] www.lanacion.com.ar/1091978-desde-2011-no-podran-venderse-mas-lamparas-incandescentes

[17] www.yonhapnews.co.kr/economy/2013/07/16/0302000000AKR20130716057151003.H-TML

efficiency improvement and renewable energy integration in the demand side will aid in the transition to a low carbon development. Public services such as hospitals will now have a means of sustainable and unlimited power supply to carry out its social duties, while reducing the need for dependence on diesel and gasoline for private power generation.

For the industrial sector, optimization of production structure and improvement in energy efficiency are vital in achieving a low carbon development. This can be promoted by energy auditing in industries such as the study carried out by Olayinka and Oladele [51]. In their study, they found out that consumption by electric motors account for 40-47% of the total electricity consumed in most industries in Nigeria. Others such as boilers and heaters account for 65% of the total energy consumed. The inefficiencies in energy use were attributed to poor in-housekeeping of air conditioner, refrigeration equipment's, weal electric motors and lack of switching off electric bulbs during the day time. These inefficiencies if addressed will resort to the reduction to about 30% of energy demand in the industrial sector.

In addition, the introduction of electric arc blast furnace for iron and steel industries should replace the conventional ones by 2040. This has great potential for the reduction of energy/electricity consumption and GHG emissions due to its high level of energy efficiency. The technology switching will increase the share of electricity in the industrial final energy mix, while reducing fossil fuel consumption. However, the implementation of this policy on a short timescale may be difficult, but can be tackled through the provision of financial incentives, subsidies, and tapping into global energy-saving funds such as clean development mechanism (CDM) and global climate funds (GCF) to help promote the industrial transformation.

For the transport sector, the use of public transport system such as bus rapid transport (BRT) system already in Lagos, Nigeria, and light rail in some part of Nigeria should be encouraged and popularized by the Nigerian government. The implementation of alternative vehicle fuels such as CNG, LPG and biomass will reduce the dependence on high GHG emitting gasoline and diesel fuels. The South Korean BRT system is comprised of mainly CNG powered buses and this move was to ensure the reduction in GHG emissions. In the Korean transport sector, LPG is also another alternative fuel besides CNG, and this intends to provide consumers with low GHG emitting fuel options. The LCA and GO scenario proved that this could be replicated in the Nigeria transport sector if the government is ready to implement some policies such as the

Autogas Incentive Policies[18] (AIP) to stimulate commuters. The AIP has contributed to the increase use of LPG for transportation in most countries around the world[19].

In terms of the energy supply sector, the reduction in T&D losses should be promoted for the electricity sector, as well as natural gas supply which is used to power SCGT and CCGT power plants. However, the Nigerian government should encourage the construction of CCGT power plants over SCGT which is less efficient. On coal power plants, more efficient combustion technologies such as IGCC, CFB and supercritical should be given more preference over the conventional coal steam power plants. Although coal power plants are higher GHGs emitting energy technology, great potential exist for carbon capture and storage (CCS) technology in the future. The Nigerian government should focus more on development of nuclear and renewables which are low carbon technologies that are vital for the attainment of a low carbon development before 2040.

The government can increase the capacity of nuclear power plant to contribute more to the electricity mix as observed in the LCA and GO, instead of the small share in the Ref scenario. This should be matched with renewables such as solar, wind, hydro, biomass, and geotherma l[20]. This actually disproves Ibitoye [20] study where his bottom-up approach using LEAP model suggest that the most-likely-development pathway for Nigerian to generate electricity to meet the millennium development goals (MDGs) was through natural gas alone. This study therefore provides electricity generation alternatives that will not only meet the increasing energy demand, but also at a lower GHG emission from sustainable energy resources.

Although this is the first study that applied a bottom-up approach to project the pathway for the complete energy system in Nigeria, grate care should be taken to understand the term "low-carbon development" in the Nigerian context. According to Conference of Parties to the

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[18] The AIP is promoted by the government through; lowering fuel tax vis-à-vis gasoline and diesel, lowering vehicle taxes or conversion subsidies, employing traffic measures and removing barriers (parking restrictions etc.).

[19] www.bpnews.com/index.php/publications/magazine/current-issue/305-world-autogas-demand-jumps-57-in-past-decade-incentives-play-key-role

[20] Although geothermal energy have not been widely popularized in Nigeria, studies [52-56] have analyzed various part of Nigeria for geothermal resources, while Kurowaska and Krzysztof [57] highlighted that the geothermal resources in Nigeria were enough to be exploited for power generation.

UNFCCC, the concept of Low Carbon development Strategies (LCDS) is a common but differentiated approach to meet the overall emissions reduction objectives: "*All countries shall prepare Low Emission Development Strategies···nationally-driven and represent[ing] the aims and objectives of individual Parties in accordance with national circumstances and capacities*" (Cancun Agreement)[21]. This means that for a developing country like Nigeria, the path towards a low carbon development should be based on the nation's circumstance, ability, capacity and the capability to go the extra mile in attaining low carbon economy. However, "low-carbon" is a futuristic development that must be pursued, but not necessarily to the goal point, but to test our effort towards a low carbon development. The low carbon developmental pathway in Nigeria is not static, but dynamic and therefore needs to be constantly amended at different stages and period in time. This study provides some likely developmental pathways through the developed scenarios for the Nigerian energy system and explored the impact of future energy policies and strategies required on the path to a low carbon transition.

4. Conclusions and Policy Implications

This study developed an energy model for Nigeria that considered vital factors capable of influencing energy policies in the future. The four scenarios developed in the model include a reference scenario and three alternative scenarios. The alternative (LCM, LCA, GO) scenarios where influenced with various level of policies and strategies to check different low carbon development pathways for Nigeria from 2010 to 2040 using the LEAP modeling tool. The results showed that the strategic policies implemented in the Nigerian LEAP model will have a significant impact on energy consumption and GHG emissions.

Under the reference scenario, energy demand in 2040 will be 3,075 PJ with a growth rate of 3.68%, with a corresponding increase in GHG emissions of 201.2 MMTCDE. This could create an enormous burden on energy and environmental system in Nigeria. Under the LCM scenario which has a moderate policy intervention, energy demand and GHG emissions in 2040 will be lower than the reference scenario by 3.53% and 185.4 MMTCDE respectively. Under the LCA

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[21] See http://cancun.unfccc.int/

scenario which has a more aggressive policy intervention, energy demand and GHG emission will be 2,488.3 PJ and 152 MMTCDE respectively. The GO scenario had the lowest energy demand of 2,249 PJ at a growth rate of 2.61% and GHG emission of 124.4 MMTCDE in 2040. Thus, to achieve such large reductions in energy demand and GHG emissions, strategic policies and technological switching is not enough despite the fact that they contributed to the reduction in energy consumption and GHG emission in Nigeria. The Nigerian government will need to do more in promoting low carbon energy technologies and energy efficiency measures through policy interventions and incentives.

The share of kerosene in the final energy consumption will increase to 24% in 2040 under the reference scenario, in contrast to a contribution of 21% and 20% in the LCA and GO, respectively. However, the share of clean energy usage, including electricity, LPG, CNG (in the GO) and natural gas will increase rapidly across the alternative scenarios, contributing more than 50% by 2040. On electricity generation, the share of natural gas power plant (SCGT) will increase to 36%, while in the LCA and GO, the share of renewables and other low carbon energy technologies will be increased. Since the focus of this study was to transit Nigeria towards a low carbon economy, the optimization of the energy structure was focused on shifting from fossil fuel to clean energy, as in the LCA and GO, which will play a significant role in GHG reduction in Nigeria.

The social cost shows that by 2040, the LCM will cost Nigeria a total of 54.9 billion US$, while the LCA will cost a total of 55.8 billion US$. A large share of the cost will come from the cost of avoiding the Ref scenario and fuel production. The GO will have the highest cost of 79.2 billion US$ by 2040, in which 13.4 billion will go for fuel production, while 53.6 billion US$ will be the cost of avoiding the situation in the Ref scenario. Overall, the household and transport sector are key areas for low carbon development in Nigeria, while the industry and commercial/service sectors are also holds great potentials in the reduction of energy consumption and GHG emissions in the coming years.

In conclusion, for Nigeria to achieve a low carbon development, it is import for the country to explore various policy options relevant in the reduction of energy demand and GHG emissions with clean energy resources. However, it is not expected to be an easy road for Nigeria to achieve a low carbon development, as some challenges cannot be ignored. For

example, the deployment of efficient cooking stoves and other clean energy technologies in Nigeria has proved challenging for the government, due to the high cost of the technologies for the consumers on the demand side. On the supply side, the cost of renewables are still very high as they require huge capital investment, and this increases the preference for fossil fuel such as natural gas. This could be addressed if the Nigerian government implement some fiscal incentives such as tax relief and exception for clean energy technology import, subsidies and loans for the purchase of renewables, and public awareness to raise interest on the benefit of clean energy technologies.

Some policy implications that could be drawn from the study. First, it is important for Nigeria to improve on energy efficiency in both the supply and demand sides through the application of modern energy technologies and practice, as this will have an impact on Nigeria's future energy conservation and GHG reduction. Second, the government should make provision for the development and deployment of alternative fuels in the demand and supply sides, as this will reduce dependence on a particular energy source such as biomass and crude oil. Third, the government should encourage the use of renewable energy technologies in both the supply and demand side through the provision of incentives such as investment tax credits, low cost loans for power generation, and increased feed-in-tariff options. Forth, the establishment of energy and environmental policies should be in favor of clean energy as this will accelerate the transition to a low carbon economy in Nigeria. Finally, the concept of low carbon development should be seen as a step in the right direction, and this should be done according to the ability, capacity and capability of Nigeria.

This research is not without limitation as some transport variables such as railway, airway and seaway transport system were excluded due to lack of available data. Also, the alternative scenarios does not exhaust the possibility of providing solutions to a low carbon development in Nigeria. Thus, more policy scenarios can be developed in future studies which will include the complete transport variables, and this will update the present study.

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Research on Future Energy Dependency Trend in Bulgarian Energy Market

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Abstract

Current research will investigate relationship between domestic economic performance and its net import and export trade balance. This research seeks to contribute in projecting future energy dependency trend based on primary energy consumption and imported energy resources, with aim to predict five year energy dependency index. Thus the paper analyze main import energy resources which compose local energy consumption, and estimate the level of energy dependency on import resources. For this purpose are proposed two different models build on artificial neural network (ANN) technique. First model is based on main energy indicators (such as total energy generation), second model is based on sectoral electricity consumption per capita. The results shows that Model1 has better accuracy, and based on it was predicted the future energy dependency trend. Based on research results was proposed recommendations to policy makers to reduce energy dependency on imported energy resources with decreasing level of distribution losses, increasing level of building energy efficiency and stimulating electrical vehicle usage and to increase the life cycle of Nuclear power plant.

Keywords: Energy dependency; Artificial Neural Network (ANN); electricity sector in Bulgaria; Renewable energy; Energy policy

1. Introduction

This paper has three main objectives of research. First goal is to identify related indicators between energy consumption and economic activities (such as local energy resources; main import energy resources; installed renewables power plants, import/export balance). This knowledge will help for better understanding the relationship between energy demand-supply and imports of primary energy resources. This is important to show the financial dependence of foreign currency, sectorial economic activities and most important is to see negative import/export balance. From decades Bulgarian economic has negative trade balance, and import of primary energy resources significantly affected it. The research had tried to identify main sectorial domestic energy consumption (industry; transport; agriculture; households; services). This will help to monitor main trend of energy consumption by economic sectors. Then to find ratio of primary energy production to consumption (RPC), which is the main indicator in calculating energy dependency.

The goal of this research is to estimate increase or decrease of energy dependence at national level associated with imported primary energy resources and energy consumed by sectors. Data was collected from Eurostat, and had content information for all variable in the period between 1990 and 2014. Expected outcome for academia is to provide evidence of extension of ANN model to local energy market of Bulgaria with estimating energy dependency under import of primary energy resource and subsequent negatively influence in the country foreign currency balance. Here are delivered practical implications with providing comprehensive research on energy dependency estimated with ANN model. Research result would being useful to local authorities to understand short coming trend of country energy dependency.

To my knowledge there are no other studies of energy dependence of Bulgarian energy market published before. There are some other studies of ED of neighbor countries (Sozen, 1009; Zamani, 2009), but they do not consider that local energy demand affect import/export trade balance.

2. Literature review

Level of primary energy resources are limited and Bulgaria has to import nearly 60% (at 2014, Nacional statistic institute) of them from abroad. Sozen (2009) argue that the high level of import of primary energy underline the country's limited indigenous energy resources. He recommend in proper energy planning at least time period of a decade of energy consumption it should be predicted.

Academia studies carried out on different energy consumption forecast using variety of methods and approaches in recent years (Sozen, 2009; Zamani 2007). Estimate of final energy consumption deliver important facts, which takes part of government decision making energy planning processes. Couple of studies analyzed energy consumption forecast using variety of methods and approaches in recent years (Kumar et al, 2010; Compton et al, 2005; Zamani et al, 2007; Sozen, 2009; Neto et al., 2008; Hamzaçebi et al., 2008; Huang et al., 2011). In past years, regression analysis was the most common analysis model predicting energy consumption. However recently hiring artificial neural network (ANN) in energy applications is more attractive for the potential users. Especially useful in analyzing energy data where mathematical formula and prior knowledge on the relationship between input and output are unknown (Günther and Fritsch, 2008).

This study reveals firstly to estimate energy dependency on main energy indicators (such as total production of primary energy per capita; net imports of natural gas per capita; total gross electricity generation per capita; final energy consumption per capita), and secondly to estimate energy dependency on sectoral energy consumption (such as final energy consumption per capita by industry; final energy consumption per capita by transport; final energy consumption per capita by households; final energy consumption per capita by service).

Bulgaria has variety of installed power plants, but resources for main of them are limited. The major operating power plants are operating with nuclear and lignite resources. To the national electricity grid are connected some alternative power plant such as hydro, solar, wind, and minority of contribution is on biodiesel and biogas. Lignite is main fossil energy resource mined domestically.

More than half of energy resources consumption (such as natural gas; petrol; uranium) are met by import, and the share of import of energy resources negatively affect country

import/export balance (table 1), and make the local electricity market energy resource dependent of its import destinations. Parami and Jonathan (2009) and Kovacevic (2009) reports about energy resource dependency after Ukrainian – Russian natural gas crisis at 2006 and 2009. After cutting the supply of natural gas from Russia (through crossing Ukraine natural gas pipes), East European countries indirectly enter the international political crises. The largest consumer of natural gas in Bulgaria are power plants and steam power plants. Transportation sector demand 30.2% (NSI, Bulgaria) of total imported oil and natural gas.

Total demand for electricity and energy resources in Bulgaria (figure 4) was growing till 2006, than the 2008-2009 Global recession chill the country energy demand, and total demand underwent significant decline, failing to return to 2001 (NSI, Bulgaria; Eurostat). Since that the energy demand has been growing, in part of following ongoing activities: growing of international trade with significant increasing level of export of services and industrial products (NSI) and import of energy resources (NSI); energy consumption generated using natural gas on the other hand grow up; trend of construction of new renewables generating capacity (such as wind power plants, solar power plants, micro hydro power plants) grew faster than new lignite capacities. Solar power remain as most expensive form of electricity generation (Haerer and Pratson, 2015). New solar power generation installed capacity grow up faster than all expanding from ground over the period to 1,04GW (Ministry of economy, Bulgaria; 2013), to achieve 7% of installed capacity including cold reserve (Electricity system operator, Bulgaria, 2013). The reasons for these ongoing shifts varied and had internal or international originate. International drivers has been changes in energy resources price (such as grow up of oil price) and EU2020 environmental protection agenda to shift down the level of consumed fossil energy resources and increase production of renewables. Internal is historically negative import/export balance, with significant large spending on imported energy resources (such as oil, natural gas and nuclear).
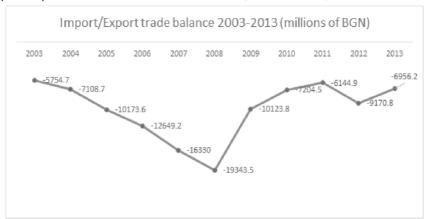
Table 1. Import/export trade balance in millions of BGN (€1 = 1.96 BGN)

Table 2. Table of real and predicted energy dependency of Bulgarian energy market

Year	Model1 Prediction	Model 2 Prediction	Real ED	Year	Model1 Prediction	Model 2 Prediction	Prediction	Real ED
1990	0.679603	0.63416	0.628792	2005	0.456395	0.488857		0.469568
1991	0.646181	0.616324	0.619335	2006	0.472241	0.47508		0.458468
1992	0.613729	0.592355	0.568808	2007	0.515342	0.456687		0.508083
1993	0.524321	0.56831	0.587297	2008	0.503918	0.407055		0.519835
1994	0.530674	0.567811	0.552329	2009	0.421695	0.396875		0.455865
1995	0.556882	0.539207	0.565467	2010	0.407694	0.39792		0.398125
1996	0.573528	0.548117	0.564395	2011	0.391324	0.412679		0.361814
1997	0.541135	0.499734	0.510668	2012	0.397222	0.417025		0.361827
1998	0.487061	0.509499	0.501462	2013	0.432902	0.405697		0.380256
1999	0.460209	0.489888	0.487095	2014	0.397227	0.41161		0.357239
2000	0.450601	0.488079	0.461296	2015	-	-	0.380256	-
2001	0.429608	0.446478	0.46075	2016	-	-	0.455865	-
2002	0.417637	0.466526	0.459421	2017	-	-	0.398125	-
2003	0.428757	0.478269	0.466755	2018	-	-	0.357239	-
2004	0.447702	0.481851	0.484422	2019	-	-	0.361827	-

3. Methodology

The research is seeking contribution to estimate future energy dependency on preserve demand-supply energy balance, through gaining knowledge of its trends cross import of energy resources and industry consumption. For this purpose are used two different models (Graph 1) build on artificial neural network (ANN) technique. The technics of applying ANN with *neuralnet* packages in R Studio developer is studied from Günther and Fritsch (2008). Structure of forecasting energy dependency is studied from Sozen (2009), were are developed two models. First model is based on main energy indicators (such as total energy generation), second model is based on sectoral electricity consumption per capita. In the both models energy dependency is in the output layer, where 10 neurons was used as hidden variables (table 3).

Table 3. Variables

|	Variables
I1	Total production of primary energy (1000 toe) per capita
I2	Net imports of natural gas (1000 toe) per capita
I3	Net imports of crude oil and petroleum products (1000 toe) per capita
I4	Net imports of coal (1000 toe) per capita
I5	Total gross electricity generation (1000 toe) per capita
I6	Final energy consumption (1000 toe) per capita
J1	Final energy consumption per capita by industry (1000 toe)
J2	Final energy consumption per capita by transport (1000 toe)
J3	Final energy consumption per capita by households (1000 toe)
J4	Final energy consumption per capita by agriculture (1000 toe)
J5	Final energy consumption per capita by service (1000 toe)
K_{ni}	Hidden variables (K_{1i}; K_{2i}; K_{3i}; K_{4i}; $\cdots$ K_{20i})
ED	Energy dependency
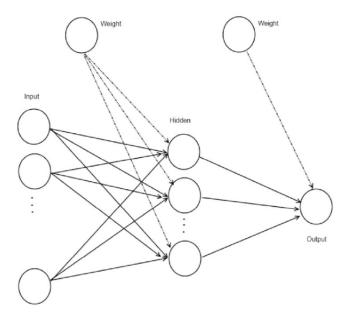
Figure 1. Structure of artificial neural network of *model 1* and *model 2*

4. Applying neuralnet

Computing neural network always is fitted to data learning by activation algorithm during data training process. *Neuralnet* is characterized by its learning algorithms, which compared the learning data between given output and predicted output by adapting all included input parameters related to this comparison. Links between all parameters in neuralnet network are weighted. Those weights are initiated as random values drawn from standard normal distribution. The training process follow the Günther and Fritsch (2010) study, where the training of the neural networks provide the opportunity to define the necessary number of hidden neurons. The number of hidden neurons underline the complexity of the model and mediate minimum learning error. Backpropagation was used in aim to find a local minimum of the error function (Riedmiller and Braun, 1993).

The activation function of *neuralnet* is "bounded nondecreasing nonlinear and differentiable functions" (Günther and Fritsch, 2010), such as the logistic Fermi function $F_i = \dfrac{1}{1 + e^{-4(E_i - 0.5)}}$. Günther and Fritsch (2010) argue that the logistic function fit the binary

response variables since it maps the results of the output neuron to the interval [0,1].

The Model 1 of the neural network is describes by the relationship between energy dependency (ED) as response variable and six covariates *primary.energy.production* (primary energy); *imports* (net import of primary energy production); *Petrol* (net import of petroleum products); *NatGas* (net import of natural gas); *Final.energy.consumption* (sum the total energy consumption); *Gross.inland.energy consumption* (sum all gross energy consumption including energy sector). Estimation of Model 1 $E_i = K_{1i} \times I_1 + K_{2i} \times I_2 + K_{3i} \times I_3 + K_{4i} \times I_4 + K_{5i} \times I_5 + K_{6i} \times I_{16}$. A neuralnet in RStudio is conduct as foolow statement

>library(neuralnet)

Loading required package: grid

Loading required package: MASS

>nn = neuralnet (ED~Primary.production+ Imports+

Petrol+ NatGas+ Final.Energy.Consumption+ Gross.inland.consumption, data=data1,

hidden=10)

>nn

Call: neuralnet(formula = ED ~ Primary.production + Imports + Petrol +

NatGas + Final.Energy.Consumption + Gross.inland.consumption,   data = data1, hidden = 10)

1 repetition was calculated.

	Error Reached	Threshold	Steps
1	0.00602538758	0.00981275637	79

$act.fct

function (x)

{

1/(1 + exp(-x))

}

Function *nn* contain basic information about Model 1, where with executing command *result.matrix* would be list all result of trained data model. The training process needed 79 steps to derivate the error function smaller than its default value of 0.01. Estimated weight range is between -2.39604636568 (Petrol - hidden2) and 4.86117869038 (Petrol – hidden4). The generalized hidden variables weight expresses the effect of each covariate K_i and thus has an analogous interpretation as *i* regression parameter in the model, and they depends on all other covariates. The weights distribution indicates whether the effect of the covariate is linear (Intrator and Intrator,2001). Additional information about the model could be conducted after computing additional commands. Command *net.results* will list the all over results in the output. Command weights list all fitted weights of the neural network for each replication. Command *generalized. weights* list the generalized weights of the neural network. Figure 2 contain graphical visualization of Model 1 generalized weights.
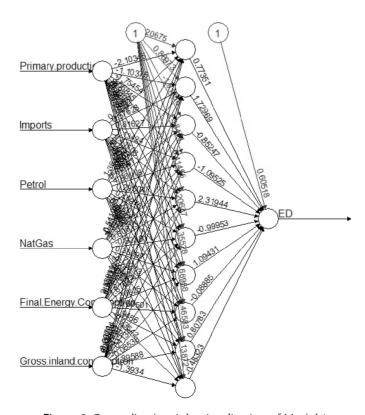
Figure 2. Generalized weight visualization of Model 1

Backpropagation is use to compare the results in the neural networks with *algorithm= "backprop"* and the package *nnet*.

>nn.bp <- neuralnet(ED~Primary.production+Imports+Petrol+

NatGas+Final.Energy.Consumption+Gross.inland.consumption,

data=data1, hidden=10, linear.output=FALSE, algorithm="backprop", learningrate = 0.01)

> nn.bp

Call:

neuralnet(formula = ED ~ Primary.production + Imports + Petrol +

NatGas + Final.Energy.Consumption + Gross.inland.consumption,

data = data1, hidden = 10, learningrate = 0.01, algorithm = "backprop", linear.output = FALSE)

1 repetition was calculated.

Error Reached   Threshold   Steps

1 0.01988382735   0.009998512925   4104

Data set of model 1 will be conducted under *nnet* package. The reason is to compare the error. Firstly *nnet* package will be activate with loading by command *library*.

>library(nnet)

>nn.net <-nnet(ED~ Primary.production+ Imports+ Petrol+

NatGas+ Final.Energy.Consumption+ Gross.inland.consumption,

data=data1, size=10, entropy=T, abstol=0.01)

weights: 81

initial value 0.299764

iter 10 value 0.024296

iter 20 value 0.014348

final value 0.009715

converged

Computing both independent packages (*neuralnet* and *nnet*), showed equal results. The results of both training processes last only a very few iteration steps and the sum of squared error is approximately 0.009. Thus shows that the model fit.

Similarly, model 2 will be conducted under same interaction with loading data set named *data2*. The graphical results are shown in Figure 3. In deference with model 1, model 2 show a

difference in comparing the error prediction. After training the dataset data2 with neuralnet package in 68 steps of training with sum of squared error of 0.016, in contrary the conducted sum of squared error in *nnet* package was 0.021. Model 1 shows smaller error, and could be concluded that the model is more significant and will be used for forecasting the next five year of energy dependency trend. The graphical comparison between real and predicted energy dependency of model 1 and 2 is shown in Figure 4.

Under *neuralnet* package, using function *nn* with dataset *data1* was executed command *prediction (nn, list.glm = NULL)* in aim to predict upcoming trend of energy dependency. The graphical result of predicted trend is included in figure 4.
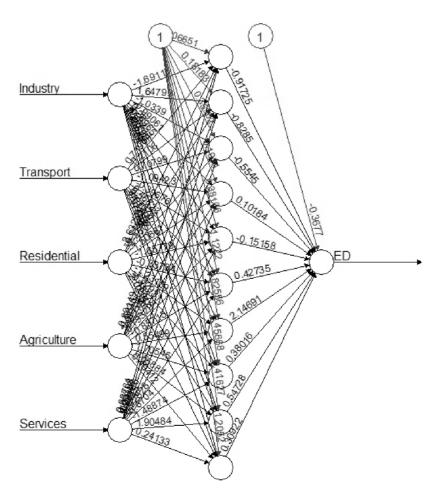

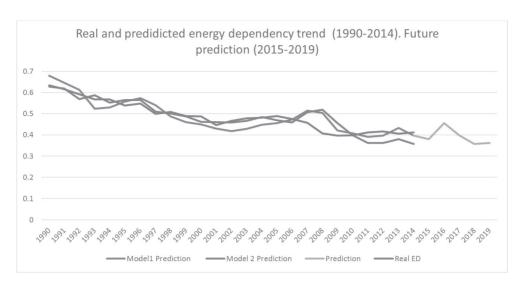Figure 3. Generalized weight visualization of Model 2

Figure 4. Shows real and predicted energy trend

5. Results and recommendations

Energy usage and utilization of energy resources theoretical regards advance and economic development and maintain of people's wealth. Around 40% of local economy energy consumption is supplied through imports since the existing local energy resources are inadequate to supply thus needs. By this demand nearly hundred percent of petroleum products and natural gas are met by importation. Following the global trend of technology catch up to rapidly advancing innovative technologies (not only industrial, but also in automobile, service and construction sector) the local government needs to utilize its primary energy resources in most efficient manner. For thus structure polices have to implemented to eliminate the risk with increasing energy dependency on imported resources. By decreasing of economic activities in early 90s, the local economy reduce its energy dependency of foreign agents. Stimulated by structural changes in the economy (massive privatization in public sector) boost the industry and service sector, which positively affect energy consumption. Dependency of imported natural gas show up during short international affairs misbalance between Russia and Ukraine on winter 2009. Another factor are petroleum product, which is main energy source for transportation sector.

Since joining European Union, Bulgarian government has promoted incentives toward utilization potential of renewable energy installations. Stimulating the investors with feed-in-tariff in short time was installed wind farms, solar panel plants, built small hydro centrals. The fast grow up of renewable sector was cooled in 2011, because the high price of feed-in-tariffs had started to threaten energy mix price and negatively affect price sensitive end customers. Nuclear energy is another primary energy resource which support energy independency. The local government have to promulgate incentives to increase the live cycle of only two out of six active reactors.

Distribution losses was not goal of current research, but the government need to hear the critics of academia (Ferel et al., 1956) for decreasing the level of distribution losses and energy inefficiency to improve its energy dependency level of primary resources. It is need to initiate more efficient policies toward utilization of energy use and to toward the lack of modernization of transmitting lines and improving the building energy efficiency.

Another factor such as average age of vehicle use was not included in this research. To decrease the usage of petroleum products in transportation sector the government need to force more incentives in utilizing use of electric vehicles and stimulate usage of rail road passenger and cargo service.

6. Conclusion

This study offer comparative analysis on energy dependency by applying two independent models under construct of artificial neural networks. The data set (collected from Eurostat between years of 1990 to 2014) of both models was conducted by *neuralnet* package in RStudio. The results was tested by estimating the same data set to second independent *nnet* package in RStudio. Comparison of both estimation, shows very high accuracy of Model 1, which was used for predicting energy dependency rate of upcoming five year (between 2015 and 2019).

Historical data shows that economy energy dependency rate decrease from 63% (in 1990) to 36% (in 2014). The energy dependency prediction shows almost flat rate for next five years. Economic development significantly will increase energy consumption. To protect, even to reduce this ration the local authorities have to utilize consumption of primary resources with

increasing the life cycle of Nuclear power plant. In other hand to stimulate electric vehicle usage in aim to decrease the dependency of imported petroleum products.

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The Effects of Rural Access to Electricity on Development of Household Enterprises in Rwanda

Godfrey Ngoboka

The Effects of Rural Access to Electricity on Development of Household Enterprises in Rwanda

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Abstract

In Rwanda, electricity access roll out programme (EARP) has been given priority since its establishment in 2008 to promote and extend electricity grid network to all people in the country. Although EARP attained a remarkable progress with in a decade, access to electricity in rural areas is still low at 6.4% compared in urban areas at 67% by 2014, and level of electrification is generally observed as a key indicator of socioeconomic development. The setback for national electrification programme is low level of electricity consumption per household estimated to 26kW per month that cannot cover utility's investment returns on grid network extension instead of 135kW per month required to confront investment returns. This makes researcher to pose a question whether rural access to electricity induces to development of household enterprises (HEs) or non-farm jobs in rural areas. HEs will supplement household income, boost household purchasing power and utility's investment returns by stimulating small scale business development in rural areas. To answer this question, the study aimed to investigate profoundly the impact of rural access to electricity in development of household enterprises in rural areas using survey data and NISR EICVs data for analysis.

The evidences present that development of household enterprises have significant association with rural electrification, and sociodemographic factors such as education, marital status, age, income. Study suggests the government to faster rural access to electricity, Inclusion of HE policies into current economic development policies, and set HE policy based on sociodemographic factors.

CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

Despite the importance of electrification for socio-economic development, around 1.3 billion people in the world live without access to electricity, and 2.7 billion people are heavily relying on traditional biomass energy for cooking which induces for dangerous indoor air pollution (IEA, 2014). Moreover, around 95% of these people are either in sub-Sahara Africa or developing Asia and 84% are in the rural areas. The lack of access to modern energy services by the poorest people particularly in the rural areas, is a major barrier to poverty reduction and socio-economic development. World Economic forum (WEF) (2009) found that access to electricity leads the expansion of enterprise activities, and also emphasized that high prevalent of lack of modern energy services in sub-Saharan Africa is therefore seen as a critical restriction on business development and employment creation in the region. Thus, clean, reliable and affordable energy services is considered as one of key requirements for boosting employment opportunities in Africa.

The rural electrification significantly enhances employment and enables the development of the household enterprises at household level which facilitates women with an alternative option to farming activities to supplement household income and contributing to national economy (Dinkelman &Taryn, 2011). According to the study undertaken by Global Energy Network Institute (2007) found that new employment opportunities identified in china's economic development process from 1980's to date was aggravated by increase of electrification and

access to electricity particularly in rural areas enabled development of small business opportunities.

Rwanda like other developing countries, access to electricity is still low around 22% and majority connected households located in the urban areas (Ministry of Infrastructure, 2015). To enrich access to electricity, the current government established Electricity access roll out programme since 2008 (EARP) aimed to improve access to reliable and cost effective electricity services to all households and priority to public institutions to confront government aspirations to electrify around 70% of households in rural and urban areas both on-grid and off-grid solution by 2018 (Ministry of finance and economic planning, 2013). Enhanced provision of adequate, affordable and reliable electricity to rural areas would therefore come in as a panacea for monotonous rural business disinvestments. Around 39% of the population in Rwanda cannot afford two dollars a day that makes them to fall under poverty line (NISR, 2015), and more than 70% of the population heavily depends on traditional agriculture (NISR, 2012). (Abbott, P. 2012), witnessed that HEs play a significant role in the socio-economic transformation of livelihood of HEs operators and in long run can contribute to government revenues through taxes, but are constrained by poor transport to access market and electricity access infrastructures combined with high costs. The government strives to attain 70% access to electricity to all Rwandans by 2018 both on-grid 48% and off-grid 52% solutions from current 22% to confront rapid economic development and poverty reduction aspirations (ESSP, 2013). However, national electrification aspiration has been criticized by many researchers to be too ambitious and unrealistic.

Although the rural electrification has been considerably important to promote livelihood of households and enhance socioeconomic conditions and reduce poverty in the rural communities. Currently, there is little or no study undertaken to analyze the contribution of rural access to electricity in the development of household enterprises (HEs) in the remote areas. This made the researcher to pose a question whether rural access to electricity induces to development of household enterprises (HEs) in the rural communities. To answer this question, the study aimed to investigate profoundly the impact of rural access to electricity in the development of household enterprises in the rural areas. To achieve this objective, we will use survey data collected from the field on households connected to electricity in rural areas from

2008-2014, NISR EICVs data and review the relevant literature.

This paper is organized as follows: Chapter two presents overview of Rwanda and details about energy sector. Chapter three indicates literature review and theoretical framework, chapter 4 Results and discussion, chapter 5 conclusion and recommendations.

CHAPTER 2: GENERAL OVERVIEW OF RWANDA

Rwanda is a landlocked country situated at the heart of the African continent, borders to the North by Uganda, to the East by United republic of Tanzania, to the South by Burundi and to West by the Democratic Republic of Congo (DRC). Rwanda has beautiful scenery including five volcanoes, lakes and numerous rivers some of them forming the source of River Nile. The country lies 75 miles south of the equator in the Tropic of Capricorn, 880 miles 'as the crow flies' west of the Indian Ocean and 1,250 miles east of the Atlantic Ocean.

The surface of Rwanda is 26,338 Square Kilometers; the average temperature of the country is 24.6°c and 27.6°c during the hottest months. The Hottest months are August and September and average rain fall is 110-200 mm per month, these geographic structures make the country suitable for farming activities the whole year. The altitude of the country ranges from 1000-4500m above sea level. Rwanda got independence from Belgium colony in 1st July 1962, and formed constitutional republic under presidential regime and the country is divided into four provinces governed by governors and Kigali city governed by Mayor, and the districts are administered by the Mayors of the districts. According to fourth National Population census (2012) presents that Rwandan population is 10.5 Million and demographic structure illustrates that female occupies largest portion of population 51.8% and male 48.2% respectively.
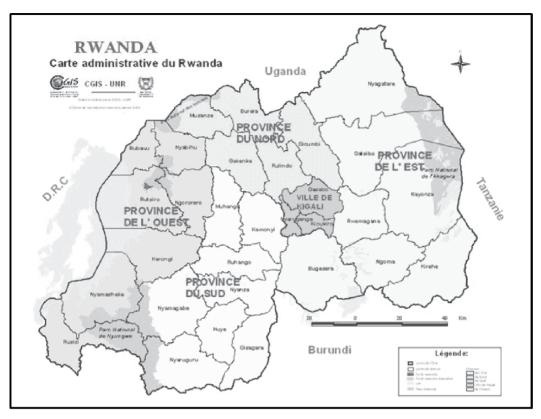
Figure 1. Administrative Map of Rwanda (Source: Ministry of East Africa, 2015)

2.1 Economic development

Rwandan economy has been significantly increasing over the past decades along with GDP per capita. The government commitment to transform economy into knowledge based presents the milestone for this achievement which stimulated investment in the industrial sector. Since the period of 1980s to 1990s the economy has been gradually increasing at low rate and later rapidly increased after 2000s due to distinct economic development policies and strategies constructed in the consultation of all sectors of economy to enrich economic growth and reduce poverty. For instance government launched long term economic development aspiration known as Vision 2020 in 2000 and medium term strategy known as Economic development and poverty reduction strategy (EDPRS) evaluated and updated every five years that expresses the purpose of attaining per capita income of a middle income country of $1,200 by 2020 (See figure 2 progress).
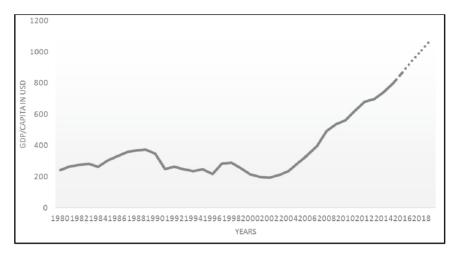
Figure 2. Evolution of Economic development in Rwanda (1980 – 2018)
(Source: Global finance, 2015)

Economy of Rwanda has been increasing at an average of 8% last five years and observed as a fastest growing nation among sub Saharan African countries. These efforts are supplemented by the conducive economic policies and zero tolerance corruption mechanisms facilitated rapid economic growth and also free market economy among the business operators. The economy is being projected to continue increasing up to 2016 based on BAU scenario (See figure 2).

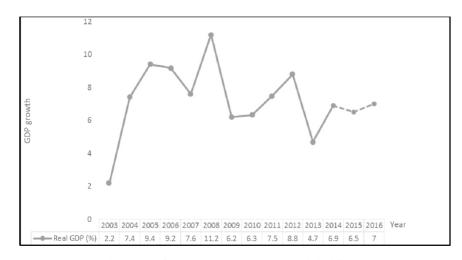|	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Year
Real GDP (%)	2.2	7.4	9.4	9.2	7.6	11.2	6.2	6.3	7.5	8.8	4.7	6.9	6.5	7	

Figure 3. Real GDP (%) from 2003 - 2016(Source: Global finance, 2015)

Generally, the economy of Rwanda for so long has been dominated by traditional form of agriculture. As the results of the government commitment, the consistence efforts has been made to transform the economy into service sector and enrich investment in the industrial sector. Unlike before, the services sector contributes a significant amount than agriculture sector to the national economy estimated at 53.3%, industry 14.8% and agriculture 31.9% share of GDP (See figure 4). In 2010, the tertiary sector accounted for the largest share of Rwanda's gross domestic product (GDP) at 47 percent, followed by the primary sector at 32 percent, the secondary sector at 15 percent, and the reminder at 6 percent were from Financial Intermediation Services Indirectly Measured (FISIM) and taxes (NISR,2012). Nevertheless the services sector presents more contribution to GDP, agriculture sector in aggregate still employs many populations about 73% in Rwanda (NISR, 2012).

However, like many other developing countries, in Rwanda agriculture sector experiences multiple problems incorporating low productivity affected by the small land less than a hector, rudimentary technique practices in farming activities, and low rate of modern system of farming. The agrarian reforms are currently introduced to address these issues such as population resettlement and labor quality improvements focusing on specialized trainings, land consolidation policy and promotion of agricultural cooperatives.
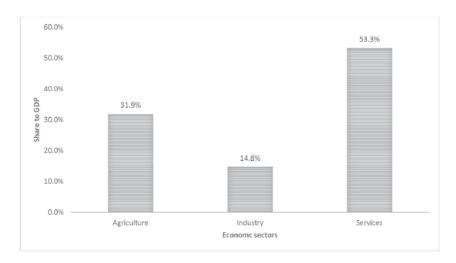

Figure 4. Share of economic sectors to GDP(Global finance, 2015)

2.2 Rwandan Population and Residence

Rwanda is most densely populated country in Africa about 416 inhabitants per Km square and 10.5 million inhabitants majority population dwells in the rural areas. The population structure is dominated by the female to male population based on four consecutive population and housing censuses from 1978 to 2012, and current population growth is 2.3% (NISR, 2012). In addition, the population of Rwanda was almost tripled from 1978 to 2012 which indicates the rapid population growth in Rwanda (See figure 4).
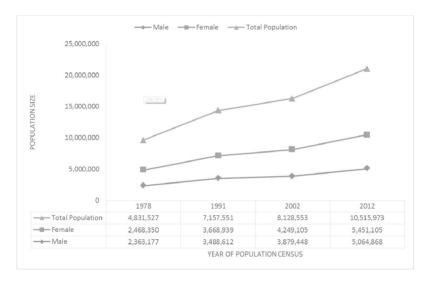

	1978	1991	2002	2012
Total Population	4,831,527	7,157,551	8,128,553	10,515,973
Female	2,468,350	3,668,939	4,249,105	5,451,105
Male	2,363,177	3,488,612	3,879,448	5,064,868

Figure 5. Population structure and size in Rwanda (1978-2012)
(Source: National Institute of statistics of Rwanda, 2012)

Population distributions by sex and age in figure 5 presents that the population of Rwanda is dominated by young about 19% are aged 19 years and below, and 82% of the population are aged under 40 years and only 3% are aged 65 years and above, among which females account for large number than male. According to EICV4, 2015 presents the percentage of women is estimated at around 52% and men 48% of entire population. This indicates the large share of the labor force and also a burden for the government to create jobs.
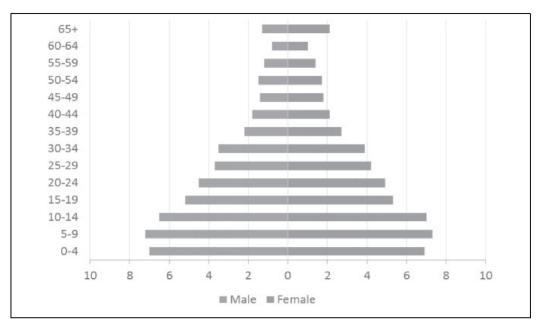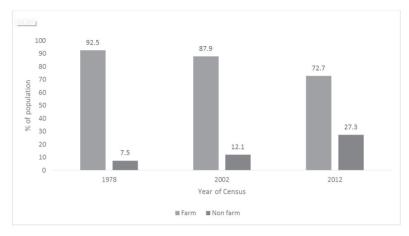
Figure 6. Population structure (%), by sex and five year age group (Source: (EICV4, 2015))

The large number of households are employed in agriculture sector about 73% of which majority are female (Figure 7). Institute of policy analysis and research Rwanda (2012) conducted a survey on development of household enterprises (HEs) and found that around 5.7 % of female and 10.3% male are employed in the household enterprise (HEs) or non-farm jobs instead of agriculture in rural areas. Some of the people owning HEs have salary employment that contributes to the family income. The population employed in agriculture sector has been gradually declining since 1978 to 2012 as presented in the population and housing censuses (Figure 7) and the number of non-farm employment increased significantly. This has occurred as results of government commitment to transforming the economic landscape into a knowledge based and service sector by reducing high dependence on agrarian farming activities by 2020 (Ministry of Finance and economic planning, 2000). According to 3rd integrated living condition survey (EICV3) (2011), presented that the significant decline of poverty from 56% to 44.9% was attributed to government efforts to eliminate extreme poverty and hunger from people through distinct economic development programs such as Girinka, Umurenge development program through ubudehe and many others. This survey witnessed that poverty largely decreased in households depending on non-farm employment than farming. Thus, the

policy promoting non-farm activities should be advocated to attain impressive economic growth and poverty reduction targets by 2020.

NB. Working age defined herein is above 15 years old and less than 65 years.

Figure 7. Share of farm and nonfarm employment in Rwanda (Source: NISR, 2012)

2.3 Energy development in Rwanda

Rwanda like many other developing country is suffering the energy poverty and limited access and supply of modern energy services. Kebede et al. (2010) presents that the limited access of modern energy services hinders economic development. Currently access to electricity is around 22% from 2.3% by 1990 and the government envisaged to attain 70% by 2018 (MININFRA, 2015). The per capita electricity consumption is one of the lowest in the Africa estimated to about 26 kWh per person causing immense problem for sustainable extension of electricity infrastructure by utility company fail to recover return to investment (CIA, 2014). Also average per capita primary energy consumption in sub-Saharan Africa is around 0.6 tonnes of oil equivalent, for Rwanda is only just over a quarter of this level 0.17 toe per capita per annum, while Industrialized country levels are 4.7 toe per capita per annum (Mpazimpaka. E, 2012). The studies present that energy access is associated not only with GDP but also with broader measures of development, such as the human development index (HDI). The figure 8 illustrates the energy development progress and government efforts to boost electricity access in urban and rural areas of Rwanda. Since 2000 to 2013, access to electricity

almost tripled from 6.2% to 18% at national level. Rural access to electricity is still a puzzle at low rate of 0.5% in 1990 to 6.4% in 2013 whereas in urban areas increased from 31% to 67% respectively.
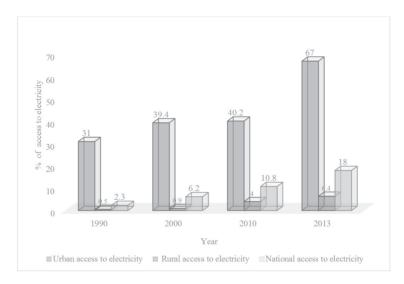

Figure 8. Access to electricity by households (1990-2013) (Source: World Bank, 2014).

The primary energy source is dominated by traditional biomass energy (firewood, charcoal and agricultural wastes) mainly used for cooking. Biomass energy account to 85%, 11% petroleum products principally used in the transport sector and 4% electricity (See figure 9). The government plans to reduce the high dependence on traditional biomass energy from 85% to 55% by 2018 due to its negative implications to human health, environment and economy (MININFRA, 2013).

Lack of access to modern energy services primarily affects women and children who spends their most of time collecting firewood and cooking, and bear negative impact of indoor air pollutions from use of traditional biomass energy that causes respiratory diseases and ultimately many people lose their lives. Thus, access to clean and modern energy services are vital to improve gender equality and economic development of the nation. (World Bank, 2011; Lambrou&Piana, 2006) presents that the precious time and labor spend by women in fuelwood collection undermines their chances to participate in the income generating activates like development of small businesses and participate social cohesions. Thus, this holds them into

vicious circle of poverty when continues to lack access to modern energy services and affects the opportunities for education, income generating activities and standards of living of their families.
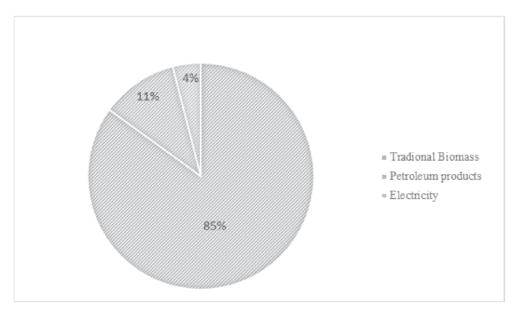

Figure 9. Primary energy balance in Rwanda (Source: Energy sector strategic plan, 2013-2018)

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 Introduction

Currently, lack of access to electricity has been considered as a major obstacle to the economic growth and development of rural economies. The studies presented that rural electrification has significant impact on small business development and rural livelihood transformation. Nonetheless access to modern energy services in remote areas has been tremendous observed to be important for socioeconomic development, around two billion people live without access to electricity especially rural areas of developing countries (IEA, 2014). Studies indicate that limited access to electricity services hinders domestic and FDI explicitly affects macroeconomic performance of the country due to great dependence on imported products than internally manufactured (World Bank, 2008). Moreover, access to

reliable electricity supplies underpin product value addition especially small and medium enterprises that involves in agribusiness activities (MINICOM, 2010). However, expensive and inadequate electricity supply induces micro and small scale enterprises such as hair salons, coffee husks, wood processing mills, maize mills and cinema show and others decide to use diesel generators at exorbitant costs. It is well noted that the cost of electricity has a significant impact to the cost of Doing Business especially by rural based household enterprises (HEs) or non-farm enterprises.

3.2 What is Household enterprise (HE)?

According to (Gordon&Craig, 2001; Abbott, P. 2012) defines Household enterprise (HE) as an owner operated small business that is normally in the informal sector and does not employ paid workers on a regular basis but may use family members to contribute without paid labor and are significantly counted as an economic gains to the households such as tailoring, Hair saloon, hawkers, shops, sewing etc. Household enterprises are activities that are not primary agriculture, forestry or fisheries but does include trade and the processing of agricultural products even when undertaken on the farm. Household enterprises or non-farm enterprises are smallest form of enterprise and distinguished from even Micro and small enterprises (MSEs) (Gaal. A, 2010). As majority work force are engaged in agriculture sector about 73% particularly in rural areas (NISR, 2012). Agriculture sector is made up of seasonal and offseason labor and therefore, households necessitate to acquire extra cash through the year by utilizing offseason as the reason for HE development. In urban areas, HEs are operated by workers with limited education or skills to meet regular salary jobs. The HEs development and its role for economic development and poverty reduction has also observed in the "Asian tiger" countries (Haggblade et al, 2010). Around 40% of households heavily depend on HEs in Sub Saharan Africa (SSA) operated by a single individual or assisted by the family members although HEs are usually undermined in terms of developing their specific support strategy in the low-income SSA (Louise.F & Thomas.P, 2012).

Household Enterprises are an important source of non-farm employment jobs in Rwanda and play a significant role in poverty reduction and providing decent jobs instead of relying on traditional form of farming. The HEs operators benefit from supplementary income generating

activity apart from agriculture and gradually their inform businesses are transformed into formal businesses that contribute directly to the national revenue through taxes and job creation. The HEs operators are generally increasing in Rwanda due to land pressure and high population growth rate 2.3% as a share of the land per person is significantly declining and people has to find an alternative economic activity to confront their daily family demands (IECV3,2011). The study conducted by IPAR, Rwanda (2012) found that many households presented additional income generating activity around 60% was household enterprises particularly in the rural areas. The majority of these HEs about 86% operate in the service sector indicating the contribution of HEs in the high growth of service sector from 2000 to 2010. The growth of HE operators has been increasing rapidly in the rural areas where the share of HEs operators increased from 15% to 28 % from 2001 to 2006 in Rwanda. In rural area, households obtained an opportunity to diversify to additional employment to assist them to boost their standards of living (IPAR, 2012). Based on the literature indicates that rural households that possess more than one income sources tend to report many working hours per month that attributed to higher annual earnings(Fox and Pimhidzai, 2011)
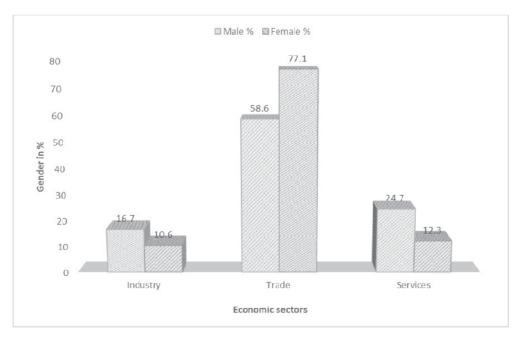

Figure 10. Industry Sector of Household Enterprises, by Gender, EICV 2005/6 (Source: NISR, 2006)

The figure 10 above presents that industrial sector of household enterprises is dominated by trade activities about 71.1% female and 58.6% male HE operators. The most trade activities involved by female HE operators are wholesale and retail trading. Male HE operators are also found in the services particularly in transport (Motorcycle taxi, cycle taxi), communication and service jobs (welding, construction, and mechanics). In manufacturing sector, male dominates female HE operators about 16.7% and 10.6% respectively. The manufacturing includes basket weaving, tailoring, knitting, carpenter arts and crafts, brick making, brewing and selling food and beverages. However, household enterprises are commonly undermined by the low income countries especially in Africa instead of promoting them through designing coherent policies and strategies for HEs operators rather than confusing them with Micro enterprises. (MINICOM, 2006) conducted a study on the informal sector and have never distinguished HEs from other micro enterprises as appeared in many other studies for instance, *Rural Micro and Small Enterprises Promotion Project* , Rwanda refers to micro and small scale enterprises (MSSEs) but these enterprises are often referred to as SMEs causing confusion with small and medium sized enterprises. This leads HEs excluded entirely from government support for example SME policy is sole limited to enterprises with hired and paid labor which does not include HEs. This presents how HEs are undermined and misunderstood by distinct category of government rather than formulating explicit policy framework and coordinating body to promote them.

Some studies examined the contribution of access to electricity on small scale business development in the developing countries. For instance, Prasad and Dieden (2007) examined the impact of electrification on the development of micro, small and medium sized enterprises and Household enterprises in South Africa, and found that access to electricity stimulates the development of small business enterprises and HEs activities in particular by around 53%. Kirubi et al. (2008) conducted similar study in Kenya and found that access to electricity facilitated many people to form non-farm enterprises and HEs including retail shops, grain mills, petrol garages, welding and carpentry businesses and contributed significantly to household income and new employments opportunities and alleviated poverty. In a study conducted on the HEs in SSA found that eight countries present that household enterprises generated many new jobs apart from agriculture and trend is projected to increase significant in

future (Louise. F & Thomas.P.S, 2012).

3.2 The relationship between rural electrification and Household enterprises development

Rural electrification presents multiple benefits incorporating socioeconomic development, employment opportunities, and development of micro and household enterprises and promotes entrepreneurship as well as improving household standards of living and poverty alleviation (Dinkelman &Taryn, 2011). Limited access to electricity in rural areas is an emerging issue in the world to date, and many organizations including World Bank focused to promote access to electricity and other forms of modern energy technologies in the developing countries. Shaindur R et al. (2013) revealed that rural access to electricity has significant impact on household income, expenditure, education and poverty alleviation. Many studies tested empirically relationship between access to electricity and economic development, and found that there is strong relationship as postulated in the recent literature (Ozturk, 2010).

The early scholar investigated the role of HEs and micro-enterprises in fostering economic development and poverty reduction, presented importance of electricity access as a principle component for small firm development in developing countries (Little, 1987; Tybout .J, 2000; Abbott. P, 2012; Neelsen & Peters, 2011). Moreover, these studies witnessed and acknowledged the impact of access to electricity in the development of household enterprises or non-farm enterprises in the developing countries. These small business enterprises or HEs contribute significantly to alleviate poverty, improve households living standards and economic growth of developing economies. However, study used survey data from 1995 to 2004 examined the impact of electrification on the development of micro, small and medium sized enterprises by Prasad and Dieden (2007) found that about 40 to 53% of developed enterprises was attributed to access to electricity from grid extension, presenting that the small enterprises increased in the areas already connected than unconnected to electricity. The uptake was mainly attributed by the increase of the cellular telephone technology in the remote areas to enable them charging battery.

In studying the impact of rural electrification on rural microenterprises in Niger Delte in Nigeria using a log-linear regression model, they found that the microenterprises or non-farm

enterprises have access to electricity are more profitable with high standards of living than non-connected communities (AKPAN, et al., 2013). According to (Bunther Bensch et al., 2011) emphases that electrification constitutes an exogenous technology impulse principally promotes microenterprises in rural areas to improve their productivity. However, when electricity is used sole for household activities such as lighting, television and charging mobile phones cannot add up to economic growth instead of creating other income generating activities such as non-farm jobs. (Agoramoorthy and Hsu, 2009) affirmed that use of modern energy services promote HEs and microenterprises by allowing the operators to extend working time even night time like sewing, tailoring and handcrafts than before connection. Despite many studies present the role of rural electrification in the promotion of small business enterprises but it is difficult to measure the extent to which electrification alone accounted for the positive outcome. Mapako.M and Prasad.G (2007) used a different approach to examining basic indicators by focusing on end users and 73 enterprises in Matebe land in Zimbabwe, and found that rural electrification increased the number and scope of small enterprises and created more employment. The study shows that respondents were more concerned about power supply reliability instead of high tariff imposed to them. Access to modern energy services enabled the remote Indians to develop household enterprises or small business enterprise activities such as sewing and handcrafts where sewing machines connected to the power were commonly used by the women to generate income apart from agriculture.

However, there are other studies conducted in Sub Saharan Africa that possess controversial arguments that rural electrification does not induce the development of HEs or micro-enterprises. For instance, the study undertaken in Namibia also found that electrification did not have a significant impact on increase of micro-enterprises to enable income generating activities in rural areas (Wamukonya and Davis, 2001). The results show that the figures for HEs developed were highest in the non-electrified areas than electrified. These HEs includes basket weaving, cake making and welding and few of them were using electricity apart from lighting. All these HEs began before electrification and overall findings never underpin any association in Namibia. The study conducted in Uganda to assess the impact of access to electricity on micro-enterprises using quantitative firm level data from 200 enterprises found that, there is little direct impact on electrification to firm profits or work remuneration (Neelsen & Peters, 2011).

CHAPTER 4. RESULTS AND DISCUSSION

The study uses quantitative data to analyze association between rural access to electricity and development of HEs in the rural areas. We assume that households who formed household enterprises or non-farm jobs after access to electricity, was attributed by rural electrification. The study measures association between access to electricity and development of HEs; and the role of demographics and individual characteristics on HEs development. The study was focused on households connected to electricity either national grid or off-grid solution from 2008 to 2014 on the time of survey. The sample size is 309 rural households covering four province and Kigali city including 10 districts. The study also used integrated household living condition survey data and other relevant literature on HEs development in Rwanda. The survey results presents that about 39% of households created household enterprises (HEs) as results of rural access to electricity although there might be some other factors contributed for its development. The results also found that there is significant association between access to electricity and HE development in rural areas. Study reveals that round 37% of households had HEs prior access to electricity and access to electricity attributed to its performance and sustainability. Using cross tabulation analysis, the study identified relationship between the sociodemographic and development of household enterprises or non-farm enterprises assuming other factors remain constant.

Table 1. Cross tabulation of Sociodemographic and Households operated HEs after access to electricity

	Yes	No	Had HE before access to electricity
Education * HHs developed HEs after access to electricity Cross tabulation			
Primary level	80(66.7%)	34(44.7%)	76(67.3%)
Secondary level	24(20.0%)	13(17.1%)	18(15.9%)
TVET	7(5.8%)	9(11.8%)	11(9.7%)
University level	1(0.8%)	4(5.3%)	5(4.4%)
No formal Education	8(6.7%)	16(21.1%)	3(2.7%)
Total	120(100%)	76(100%)	113(100%)

Chi-Square (X^2) 29.461 with df: 8 P-value: 0.000 sign. ($\alpha = 0.05$)

	Yes	No	Had HE before access to electricity
Marital status * HHs developed HEs after access to electricity Cross tabulation			
Married	59(49.6%)	44(57.9%)	73(65.2%)
Single	48(40.3%)	13(17.1%)	33(29.5%)
Widow	5(4.2%)	12(15.8%)	4(3.6%)
Divorced	7(5.9%)	7(9.2%)	2(1.8%)
Total	119(100.0%)	76(100.0%)	112(100.0%)
Chi-Square (X^2) 27.522 with df: 6 P-value: 0.000 sign. ($\alpha = 0.05$)			
Gender * HHs developed HEs after access to electricity Cross tabulation			
Male	86 (71.7%)	47(61.8%)	68(60.2%)
Female	34(28.3%)	29(38.2%)	45(39.8%)
Total	120(100.0%)	76(100.0%)	113(100.0%)
Chi-Square (X^2) 3.835 with df: 2 P-value: 0.147 insign. ($\alpha = 0.05$)			
Increase of working hours * HHs developed HEs after access to electricity Cross tabulation			
Yes	116(96.7%)	46(86.2%)	113(100%)
No	2(1.7%)	8(14.8%)	0
NA	2(1.7%)	0	0
Total	120(100%)	54(100%)	113(100%)
Chi-Square (X^2) 28.60723 with P-value: 0.000 sign. ($\alpha = 0.05$)			
Access to internet * HHs created HEs after access to electricity Cross tabulation			
Yes	96(80.0%)	23(42.6%)	106(93.8%)
No	19(15.8%)	27(50 %)	7(6.2%)
NA	5(4.2%)	4(7.4%)	0
Total	120	54	113
Chi-Square (X^2) 58.126 with P-value: 0.000 sign. ($\alpha = 0.05$)			
Age * HHs created HEs after access to electricity Cross tabulation			
16 - 25	41(34.2%)	5(6.6%)	33(29.2%)
26 - 35	57(47.5%)	27(35.5%)	34(30.1%)
36 - 45	18(15.0%)	26(34.2%)	31(27.4%)
46 - 55	2(1.7%)	11(14.5%)	10(8.8%)
56 - 65	2(1.7%)	3(3.9%)	0(0.0%)
> 65	0(0.0%)	4(5.3%)	5(4.4%)
Total	120(100.0%)	76(100.0%)	113(100.0%)
Chi-Square (X^2) 48.318 with P-value: 0.000 sign. ($\alpha = 0.05$)			

Source: Survey data, 2014

The study results present that immense number of households developed household enterprises (HEs) after access to electricity in rural areas have completed primary education level about 67%, secondary education level 20% and technical and vocational training education level around 6% and others had insignificant figures respectively. The study indicates that increase of household education level increases the likelihood for operating HEs, and decreases when household completes secondary education and tertiary education because people tend to look for paid jobs. These results comply with IPAR- Rwanda survey results indicates that HE operators decrease as education level increases from secondary school and above, people tend to join paid wage (IPAR, 2012). Analysis of results also reveal that large number of HE operators but started before access to electricity have completed primary education level about 67%, secondary education level around 16% , and HE operators' tend to decrease when education level increases above secondary education level. The empirical results indicate that, there is significance association between education level and development of HEs in rural areas of Rwanda (see table 1).

The study evaluates the influence of marital status of respondents and development of HEs or nonfarm enterprises in rural areas. The finding presents that large number of households created HEs after rural electrification were married about 50%, followed by single 40% while widow and divorced respondents has less likelihood for creation of HEs at 4% and 6% respectively. Study results also present that married and single households are still dominant for operating HEs in the rural areas considering prior and post rural electrification. This study results found that there is significant association between marital status and development of HEs in rural areas after access to electricity because chi-square statistic (27.522) with degree of freedom (6) is greater than P-Value: 0.000 at the 5% level (See table 1). However, the chi-square test provides the association between the variables but does not provide magnitude of correlation.

The study reveals that the majority households who started HEs after rural access to electricity were men about 72%, and female around 28% female respectively. The overall results show that many HE operators are men than women considering prior and post rural electrification. However, the evidences show that these variables are not statistically significance and there is no relationship between gender and development of HEs in the rural

areas. The finding presents that households created HEs about 97%, have increased working hours after rural electrification. The empirical results show that there is strong relationship between increasing of working hours after access to electricity and development of HEs or non-farm jobs which are statistically significant. Moreover, the majority of households owned HEs prior rural electrification, have increased their working hours after access to electrification. This has enhanced the business performance and sustainability of HEs.

The finding presents that about 80% of households started HEs after rural electrification have access to internet services, and 15% no internet access services. The study also shows that around 94% of households interviewed had HEs before access to electricity, have access to internet services especially from mobile phone and about 6% no access to internet services. This implies that rural access to electricity provoked many households to purchase mobile phones which helped them to use internet either by coordinating their businesses or with friends through different social network platforms including Kakao, WhatsApp, Facebook and Viber etc. The evidences present that there is association between access to internet and development of HEs after rural electrification.

The analysis of study shows that majority HE operators have age group between 26 to 35 years old estimated at 48%, followed by age group of 16 to 25 about 34%, age group of 36 – 45 years old around 15% and others have insignificant figures. Generally, the majority HE operators are youth found in the range between 16 to 35years old. The age group of 26 to 35 years old and 16 to 25 years old are still dominating categories of HEs operators who started non-farm jobs prior rural electrification. The study results portray that there is significant association between age of respondent and development of HEs in the rural areas after electrification with chi-square statistic (48.318) greater than P-Value at the 5% level. This simply means that age of respondent influences the development of HEs in the rural areas. Yet, the old people are unlikely to develop HEs despite of having access to electricity in rural areas. Contrary to other previous studies undertaken in Rwanda for instance IPAR, Rwanda 2012 found that the probability of owning HEs increases with age, and old people are more likely to own HEs although the study presents overall picture of the country than the current study focuses on rural areas accessed electricity. The rationale for majority youth to operate HEs is the issue of population density that put pressure on population to look for non-farm activities since

land ratio per person is declining, youth devoted to start HEs mostly like do not necessitate large land and capital to start business such as Hawkers, small shop, tailoring, motorcycle taxi, bicycle taxi, art and crafts. The population structure of Rwanda is dominated by youth more than 60% above 15 to 35 years old and majority of them have minimum level of education neither secondary nor university education (NISR, 2012). Therefore, the sole remedy for survival is to operate HEs to supplement farming activities in order to boost their standards of living in rural areas and access to electricity played a significant role since many salons, tailoring, welding, shops, local beer bars, and transport activities have augmented.

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

Many studies in sub Saharan Africa presented that lack of access to electricity infrastructures has condemned to be the setback for poor economic performance. For instance, (Esfahani and Ramirez, 2003) found that poor economic performance and development of sub-Saharan Africa constrained by under investment in electricity and telecommunications. In Rwanda, household enterprises have been hindered by several factors including access to electricity infrastructures to enable them perform better and increase the quantity and quality of their businesses and create more new non-farm jobs. access to electricity alone is not sufficient to achieve desirable social economic development goals but also Policy makers, donors, non-governmental organizations (NGOs), and other actors engaged in rural development must both make decisions considering the scale of distributive generation programs, and reflect on end-users' needs and productive uses for electricity if rural electrification projects are to result in long-term development benefits. By doing so, rural households should be sensitized to take leading role in innovations, and invention of new types of employment which not only linked with agriculture rather nonfarm activities.

HEs play a significance role in the social economic development and non-farm jobs that improves livelihood of the people and reduce poverty. This sector has been growing tremendous within two decades because of various factors including rural access to electricity and economic development policies of the country. Yet agriculture sector still employs many people over 73% of entire population, around 30% of households depend on HEs income. The studies present that

there is large share of HEs operators in rural areas that diversify their income portfolio that contributes to their living standards. Thus, it plays greatest role for rural livelihood transformation and poverty reduction. HEs serves as an engine for women to participate in economic activities, yet the studies show that the share of women active in HEs are still low in Rwanda (see table 1). There are several factors influencing HEs from raising their income and productivity in Rwanda some of them are; lack of access to market, lack of access to electricity, unrecognized sector by the government, lack of specific policy to promote HEs and access to finance from financial institutions to widen their small businesses. The findings of the study presents that there is an association between HEs participation and increasing the level of education with higher income earnings. The study found that there is a significant association between access to electricity and development of HEs in the rural areas. Also, there are other reasons that attributed to development of HEs in rural areas such as education level, increase of working hours ,marital of the respondents, access to internet, age, marital status of respondents also have significant associated with development of the HEs after access to electricity in rural areas. This implies that after rural access to electricity, many people reported to have developed non-farm enterprises (HEs). To promote and strengthen HEs and productivity, study recommends the following;

1) Government to incorporate HE policies into current economic development and poverty reduction strategy to ensure that HEs benefit from its targeted programs if government wants to attain its aspiration of reducing extreme poverty from 39% to 20% by 2020.

2) To Faster rural access to electricity from 6.4% to 70% to confront government commitment which will facilitate households to set up, operate and establish sustainable HEs, and reduce overreliance on agriculture sector in rural areas.

3) To set rural development policy based on sociodemographic factors to ensure that gender, marital status, education, income of rural people are considered to accelerate a well functional policy for HE development.

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