The Final Energy Consumption Characteristics of the G7 and BRICS Nations

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Abstract. Group of Seven (G7) and BRICS have an important position in many spheres, the research on these countries’ final energy consumption is necessary and important. It will provide China with the experience on "low-carbon development" and "energy saving". The research indicates that in the final energy consumption structure of the G7, oil and natural gas occupy the higher proportion. As for the BRICS countries, the proportion of coal, renewables & and waste is much higher. G7 countries’ transport sector, business and the public sector are higher than the proportion of BRICS countries, while the proportion of BRICS countries is higher than the Group of Seven industrial sector.

1. Introduction
Energy has always been the focus of global attention. Since the Industrial Revolution, the burning of fossil fuels has caused global carbon emissions to rise sharply, which has led to global warming. As resources are exhausted and the drawbacks of traditional energy use continue to emerge, the rational and effective use of energy has gradually become an important deciding factor in a nation’s realization of sustainable development. Studying the characteristics of the energy consumption of major countries allows us to uncover their experiences in green development, and provides [important] lessons in energy conservation and emissions reduction for China and other countries.

Research by scholars such as Zhang Deyi [1] and Liao Hua [2] predict that future energy consumption will further increase; scholars such as Luan Yan [3], Liao Hua [4] and Wang Qiang [5] point out differences in energy consumption patterns among different countries as well as regional imbalances. Much of the current body of research focuses on primary energy consumption; some research focuses only on certain countries and regions. Part of the current scholarship [in the field] focuses on relatively short time horizons [6, 7].

This paper studies the final energy consumption patterns of the G7 and BRICS nations from 1991 to 2015, discuss these topics separately according to sector and energy [type], and conduct a comparative analysis of the energy consumption characteristics of the residential sectors of these nations, with the goal of summarizing the restructuring of energy consumption patterns in various nations, and thus acquire lessons of practical value regarding the “low-carbon development” [strategies] of various nations.
2. Methodology and Data Analysis
Building on the past body of scholarship on energy consumption, this paper shall mainly analyse the characteristics of final energy consumption. Apart from the industrial and transportation sectors, this paper shall also evaluate the energy consumption of the residential, commercial and public services sectors. Though the nations considered are currently in different stages of development, [and thus] display significant differences in energy consumption patterns, but their residential sectors generally account for approximately 20% - 30% of the final energy consumed. From this we can see that [rational use of energy] in the residential sector will contribute greatly to the nation’s overall energy conservation, emissions reduction and low-carbon development [efforts]. Hence, this paper shall place particular emphasis on the comparative analysis of the characteristics of energy consumption in the residential sectors of various nations.

This paper uses the World Energy Balances for non-OECD nations between the years 1991 – 2015 published by the International Energy Agency (IEA), as well as the latest World Energy Balances for OECD nations as primary sources, and uses descriptive statistics to analyse the final energy consumption characteristics of the G7 and BRICS nations. International comparison and international experience methods are also used to conduct horizontal and vertical analysis of the changes in energy consumption structure in each of the major countries to finally arrive at conclusions regarding their experiences in energy consumption and energy use.

To make our analysis and comparisons more convenient, the energy consumption statistics of the residential and commercial and public services sector referred to in this paper are considered independently. The “Others” category includes all sectors that use energy apart from the industrial, transportation, residential and commercial and public services sectors. As the Soviet Union dissolved in 1991, and was replaced by the Russian Federation, this paper assumes the relevant statistics for Russia to be zero. In order that our data analysis can be more efficient, our analysis begins from 1991.

3. Discussion and Analysis of Results

3.1. The Final Energy Consumption Metrics of Major Nations
As shown in Figure 1, the total final energy consumption of the major nations of the world are influenced by many factors, such as population, stage of development, natural resource endowment and technological progress. In the preceding two decades, the energy consumption of countries in different stages of development show relatively large differences.

![Figure 1. Total energy consumption of major countries in the country.](Image)
Note: toe is the abbreviation of tonne of oil equivalent, as below.

We can observe from Figure 1 that in the years between 1991 and 2015, the total final energy consumption of the G7 nations have been relatively stable, amongst which the total final energy consumption of the USA is the largest, and also shows relatively larger variations. The USA’s total final energy consumption peaked in 2007, at a level of 1571.6 million toe. The 2008 Global Financial Crisis dealt a strong blow to the American economy, and the USA’s total final energy consumption decreased consecutively in 2008 and 2009, to 1525.3 million toe and 1442.2 toe respectively, a total decrease of 83.1 million toe, equivalent to approximately 5.4%. The American economy gradually picked up after 2010, and total final energy consumption increased to a certain extent.

The BRICS nations saw a steady increase in total final energy consumption between 1991 to 2015, with the [notable] exception of Russia. After the 1990s, “Economic Globalization” gradually emerged and became an unstoppable trend. Developing nations began to rise, and became the foundries of the developed nations. Their total final energy consumption began to increase as their economies developed.

From Figure 1, we can [also] see that the total final energy consumption of the BRICS nations grew at an increasing rate after 1991, amongst which China and India saw the highest rate of increase. China’s total final energy consumption increased from 507.4 million toe in 1991 to 1905.7 million toe in 2015, while India’s total final energy consumption increased from 122.4 million toe in 1991 to 577.7 million toe in 2015. The economies of Brazil and South Africa developed at a slower pace, and their total final energy consumption levels [correspondingly] increased at a slower rate. Energy superpower Russia saw a relatively large decrease in total final energy consumption from 487.8 million toe in 1991 to 388.1 million toe in 1998. Russia’s energy consumption levels were largely stable from 1998 to 2013. Due to the 1998 Asian Financial Crisis, the total final energy consumption of Russia, India and China saw varying levels of decline, China’s being the largest, followed by Russia and India.

Before 2011, the USA was the largest nation by total final energy consumption among these 12 nations, and also the largest energy consumer nation in the world, with a total final energy consumption of 1487.4 million toe. Since then, China has leaped to first place, becoming the world’s greatest energy consumer nation. In 2015, China’s total final energy consumption reached 1905.7 million toe. It can be observed that the total final energy consumption of developed nations, as represented by the G7 states, has been largely stable for the past 30 years, whereas the total final energy consumption of developing nations, as represented by the BRICS, have mostly maintained growth trends.

3.2. The Total Final Energy Consumption Patterns of Major Nations

As shown in Figure 2, the final energy consumption structure of the various major nations of the world exhibit relatively large discrepancies.

Because crude oil cannot be used directly to supply energy, we need not account for it when considering the total final energy consumption of the G7 and BRICS nations. Petroleum products make up a relatively large proportion of the total final energy consumption of the G7 nations, generally between 40% to 60%, making it the main source of energy consumed. Whereas in the BRICS nations, petroleum products make up a smaller proportion of total final energy consumption, approximately between 20% to 40%.

The opposite is true when it comes to the proportions of natural gas and coal in the final energy consumption structure of G7 and BRICS nations. From 1991 to 2015, natural gas accounted for 20% - 30% of the total final energy consumption of the G7 nations with the exception of Japan (approximately 10%). Coal made up only 10% of the total final energy consumption of the G7 nations, a relatively small proportion. Furthermore, [the use of coal in the G7 nations] shows a year-on-year downward trend. Whereas in the BRICS nations, coal makes up a higher proportion of total final energy consumption, and natural gas a lower proportion. Coal’s share of China’s total final energy consumption has seen a decline of 29.7%, from 66.5% in 1991 to 36.8% in 2015. The proportion of natural gas in China’s total final energy consumption has increased continuously, but has yet to exceed 6%. Russia is endowed with rich natural gas reserves, and thus natural gas makes up 20% - 30% of Russia’s total final energy consumption. [In percentage terms], the use of coal in Russia has seen a sharp decline. The proportion
of coal and natural gas in Brazil’s total final energy consumption is modest. South Africa and India have both seen declines in the use of coal as a proportion of total final energy consumption, but coal still constitutes a substantial share of approximately 20%. Natural gas consumption is less than 5% of total final energy consumption in South Africa and India.

In the G7 nations, the use of renewable energy and biomass energy is generally modest as a proportion of total final energy consumption, not exceeding 10%, whereas in the BRICS nations, renewable energy and biomass energy make up a larger share of total final energy consumption. Even with a moderate decline over the last 20 years, the use of renewables and biomass energy in the BRICS nations (Russia excluded) is largely between 10% - 30%, with India exceeding 30%. In less developed countries, the use of renewable energy and bio-fuels is concentrated in underdeveloped rural areas, in the form of burning [traditional fuels] such as straw and firewood.

Electricity occupies an important position in the total final energy consumption of the [major nations] of the world. Its share [of total final energy consumption] is relatively modest, but the G7 nations have a significantly higher electrification rate than the BRICS nations.

The use of geothermal energy varies strongly across regions. Nations in the tropical or subtropical zones do not require geothermal energy at all. In contrast, 20% - 30% of total final energy consumption goes towards heating in Russia, which is situated in the North Frigid Zone. Nations in the temperate zones generally use less energy for heating, below 5% [of total final energy consumption].

In conclusion, commodity energy sources that are more energy-efficient and less polluting constitute a larger proportion of the total final energy consumption structure of developed nations, as represented by the G7 nations. Whereas developing nations, as represented by the BRICS nations, use more coal, renewables and biomass energy, which are less energy-efficient and more polluting, as a proportion of total final energy consumption.

3.3. The Energy Consumption Patterns of Major Nations by Sector

Figure 3 shows the energy consumption patterns of major nations by sector. Five sectors are included: industrial, transportation, residential, commercial and public services, and others.

The proportion of total final energy consumed by the industrial sector is closely linked to the nation’s stage of development. G7 nations have largely completed the industrialization process, and as the world
economy globalized, many developed nations gradually relocated their energy-intensive industrial sectors to developing nations through methods such as multinational investment. Hence, the proportion of total final energy consumed by the industrial sectors of developed nations have been declining progressively. As shown in Figure 3, the industrial sectors of the G7 nations generally account for 20% - 30% of total final energy consumption from 1991 to 2015, and show a trend of gradual decline. As for the less technologically advanced BRICS nations, their industrial sectors occupy significant positions in their [respective] economies, thus consuming more energy as a proportion of total final energy consumption, with consumption increasing [year-on-year]. But as other sectors gradually developed, the industrial sector’s final energy consumption declined moderately as a proportion of total final energy consumption. In 2008 and 2015, China’s industrial sector consumed the most energy amongst the BRICS nations, as a proportion of total final energy consumption, reaching a high of 50%. With the exception of Russia, the industrial sectors of the other BRICS nations, Brazil, India and South Africa, accounted for up to 35% of total final energy consumption. Compared to the G7 nations, [the industrial sectors of the BRICS nations] generally consume 10% to 20% more energy [as a proportion of total final energy consumption].

![Figure 3. Energy consumption structure of the terminal sectors of major countries in the world.](image)

Public roads, railroads, aviation and maritime transport mainly account for the energy consumption of the transportation sector. We can observe that in 1991, 1998 and 2015, the energy consumed by the transportation sectors of each G7 nation has remained basically unchanged as a proportion of total final energy consumption, generally between 20% - 30%. The transportation sector in the USA accounts for 40% of total final energy consumption, owing to the USA’s higher per capita ownership rate, and is also a reflection of the American “luxurious” lifestyle. The total final energy consumed by the transportation sectors in the BRICS nations have moderately increased from 1991 to 2015, but also display comparatively large variations amongst one another. The total final energy consumed by the transportation sectors in China and India are relatively low, at levels below 15% [of total final energy consumption]. The total final energy consumed by the transportation sector in Brazil is considerable in comparison, accounting for 40% [of total final energy consumption]. The transportation sectors in Russia and South Africa both account for less than 30% of total final energy consumption.
The [amount of] energy used by the residential sector in each nation directly reflects the standard of living [enjoyed by] her citizens. Quantitatively, the total final energy consumed by the residential sectors of the G7 nations do not display significant variations in these three reference years, and have remained relatively stable. Apart from Japan and the USA, the [energy consumed by the residential sectors] of the other G7 nations fall between 20% - 35%. In 2015, the residential sector in Japan accounted for only 15% of total final energy consumption. To a certain extent, it reflects the holistic approach Japan has taken towards energy conservation, and could serve as a useful reference for the energy conservation efforts of other nations. Following the swift development of their economies, the living standards of the citizens of the BRICS nations have also steadily improved, and the total final energy consumption levels [in percentage terms] of the residential sectors in these nations have also steadily increased. The residential sector in China accounted for 15% - 30% of total final energy consumption, with levels peaking in 2008 at 27%, an increase of nearly 10% on 1993, indicating a great rise in the living standards of her citizens. The residential sector in Brazil accounted for approximately 12% of total final energy consumption, while the proportion of total final energy consumed by India’s residential sector saw a larger increase, from 13.7% in 1993 to approximately 40% in [both] 2008 and 2013. The proportion of total final energy consumed by Russia’s residential sector is approximately 30%, while South Africa saw an increase from 9.4% to approximately 25%. In general, the energy consumption levels of the residential sectors in the G7 nations have remained fundamentally stable, while the total final energy consumed by the residential sectors of developing nations have increased.

The final energy consumption characteristics of the commercial and public services sector differ to a larger extent. The economies of the G7 nations are more developed, and have friendlier environments conducive to business development, and a more mature commercial and public services sector. Each of these nations also have supportive governmental policies that vigorously promote its development. Compared to the BRICS nations, the commercial and public services sector of G7 nations consume nearly 10% more energy in terms of total final energy consumption.

[Describing] the total final energy consumption patterns of the world’s major nations in terms of energy used per sector allows us to see that the final energy consumption levels of developing nations, as represented by the BRICS nations, have continually increased since the process of economic globalization began. [In developing nations], the pace of economic development has also picked up in tandem, living standards of their citizens have improved, and the energy consumed by the residential sector has increased therewith. The proportion of total final energy consumed by the transportation sector has also increased modestly, but the proportion consumed by the commercial and public services sector remains relatively low. Whereas developed nations, as represented by the G7 nations, have seen the proportion of total final energy consumed by the industrial sector decline steadily, while the proportion of total final energy consumed by the commercial and public services sector maintains an upward trend. Their residential and transportation sectors continue to maintain the same proportions of total final energy consumption.

3.4. Energy Consumption Patterns in the Residential Sectors of Major Nations
As seen in Figure 4, the energy consumption pattern of the residential sector in each nation varies significantly [from country to country]. The G7 nations mainly utilize petroleum products, natural gas and electricity. Renewables, biomass energy and geothermal energy also constitute a certain proportion [of total final energy consumption], whereas main energy sources differ across each of the BRICS nations.
Figure 4. Energy consumption structure of the residential sector in major countries of the world.

The proportion of [coal-generated energy] in total final energy consumption in the residential sectors of the G7 and BRICS nations have generally declined, among which China saw the greatest reduction [in the use of coal], from 86.9% in 1991 to 15.7% in 2015.  

[The amount of energy generated from] petroleum products, as a proportion of total final energy consumption, is clearly greater in the residential sectors of the G7 nations than in the BRICS nations. Between 1991 and 2015, energy generated by petroleum products in the G7 nations was generally 10% - 30% of total final energy consumption, and show a downward trend in both proportional and absolute terms. On one hand, the lifestyle of the citizens of these nations changed along with the times, and petroleum products [began to be] replaced by clean energy sources such as natural gas; on the other hand, owing to the 2008 Global Financial Crisis, incomes shrank substantially, and consumption levels declined somewhat, causing the final energy consumption levels and final consumption proportions to progressively decline. Apart from Russia, the other BRICS nations all saw a moderate increase in [the use of energy generated by] petroleum products in the total final energy consumption levels of the residential sector. Petroleum products account for less than 10% of the final energy consumed by the residential sector, is lower in the BRICS nations compared to the G7 nations.  

The use of natural gas varies between developed nations and developing nations. Natural gas has always been seen as a high-quality, clean and efficient energy source, which explains the continued rise in demand for natural gas all over the globe. Between 1991 and 2015, total final energy consumption has increased substantially. The amount of natural gas used, as a proportion of residential sector final consumption...
energy consumption, is 25 percentage points higher in OECD countries compared to non-OECD countries. From 1991 to 2015, natural gas generally accounted for 20% to 40% of the final energy consumption of the residential sector in G7 nations. Among the BRICS nations, the use of natural gas in China’s residential sector, as a proportion of final energy consumption, increased from 2.1% to 9.6%, while remaining below 2% in Brazil, India and South Africa. Russia is endowed with abundant natural gas reserves, and natural gas accounts for 30% of [residential sector final energy consumption], a [significantly] higher level. By comparing data from the G7 and BRICS nations, it can clearly be seen that natural gas consumption in developed nations show a “high proportion, low growth” trend, while developing nations show a “low proportion, high growth” trend.

Renewable energy sources and biofuels are mostly primary energy sources of a non-commodity nature. Renewables in the residential sector often take such forms as solar energy, while biomass energy mainly refers to found in the underdeveloped rural regions of developing nations, such as burning straw. These [biomass energy sources] are energy-inefficient, highly-polluting; the burning of biogas is more energy-efficient and environmentally friendly. It can be seen from Figure 4 that the use of renewables and biofuels in developing countries is distinctly greater than in developed countries.

The use of electricity does not cause pollution or emit greenhouse gases in itself. As income levels rise, electricity becomes a favoured energy source. Electricity accounts for 20% - 40% of final energy consumption in the residential sectors of developed nations, as represented by the G7 nations, and [exhibits] slower rates of growth. The corresponding figure for the BRICS nations, with the exception of Brazil, generally ranges between 10% to 20% in 2008 and 2015. Electricity accounts for 45% of final energy consumption in Brazil’s residential sector (Brazil is rich in hydropower resources, and mainly relies on hydroelectric energy). Overall, the use of electricity in the residential sectors of the G7 and BRICS nations has been steadily increasing, both as a proportion of final energy consumption and in absolute terms. Still, [it should be noted that] the electrification rate of the G7 nations is higher than that of the BRICS nations.

The use of geothermal energy exhibits [great] regional variation. It is more commonly used in colder regions, and less common or [even] completely absent in the tropical and subtropical zones.

In conclusion, from the energy consumption structures of the residential sectors in the G7 and BRICS nations, [it can be observed that] the use of natural gas, petroleum [products] and electricity as a proportion of the final energy consumption structure of the G7 nations is [clearly] higher than that of the BRICS nations (excluding Russia). The use of coal, renewables and biomass energy, as a proportion of the final energy consumption structures of the less economically developed BRICS nations is greater than that of the G7 nations.

3.5. A Comparison of Energy Consumption Per Capita in Major Nations

Figure 5 shows the final energy consumption levels per capita for the major nations of the world. It can be observed that the final energy consumption levels per capita are higher for the G7 nations than for the BRICS nations (excluding Russia). In 2015, Canada’s ranked 8th in terms of total final energy consumption among these 12 nations, but her final energy consumption per capita was highest among the 12, at a level of 0.954 toe per capita. This reflects the Canadian “luxurious” lifestyle. The USA ranked 2nd in terms of consumption levels per capita, with an average amount of 0.849 toe per capita (using 1991, 2008 and 2015 as reference years). Apart from Canada and the USA, the other five G7 nations’ final energy consumption levels per capita ranged between 0.3 to 0.8 toe (taking an average of the same three reference years), amongst which the Japan had the lowest final energy consumption level per capita, reflecting that the Japanese had higher energy conservation awareness, and more effective energy conservation [accomplishments]. Among the BRICS nations, Russia is endowed with rich energy resources, and her final energy consumption level per capita is basically equal to that of the G7 nations. Russia aside, the final energy consumption levels per capita of China, India, Brazil and South Africa have been steadily increasing over the past 20 years. China’s final energy consumption per capita has increased from 0.082 toe in 1991 to 0.228 toe in 2015, but has yet to reach one-third of the USA’s final energy consumption per capita. India is currently the second-most populous nation in the world,
surpassed only by China. Her final energy consumption level per capita is lowest among the 12 nations, [reaching] only 0.145 toe in 2015.

4. Main Conclusions and Lessons
Since the 1990s, the process of “Economic Globalization” has promoted the development of the world economy, and in turn triggered environmental degradation and climate change through high [levels of] energy consumption and high emission [levels]. Every nation’s need for “low-carbon development and energy conservation” has become more and more prominent. We may observe from the research conducted in this paper that by comparing different final energy consumption proportions, energy-efficient, clean commodity-based [energy sources] such as petroleum [products] and natural gas bear the characteristics of “high proportion, low growth rate” in the final energy consumption structure of developed nations, as represented by the G7. Whereas the final energy consumption structure of developing nations, represented by the BRICS nations, includes higher consumption levels of energy-inefficient and polluting [energy sources] such as coal, renewables and biomass energy, both in proportional and absolute terms. However, [the use of these energy sources] exhibit downward trends. A comparison of final consumption proportions by sector reveals that the transportation and commercial and public services sectors of the G7 nations, which have already completed the “Industrialization Process”, [consume more energy as a proportion of total final energy consumption] than those of the BRICS nations. In contrast, the industrial sectors of the BRICS nations, which are still developing [their economies], [use significantly more energy] proportion-wise. [The energy consumed by] each nation’s residential sectors do not vary much in terms of proportion of total final energy consumption, but do vary significantly in per capita terms, which reflects the imbalances in energy consumption among nations and regions.

Each nation is currently progressively adjusting her energy structure and striving towards low-carbon development, but such adjustment requires the joint efforts of all the energy-consuming sectors. When it comes to developed nations and developing nations, which are in different stages of development, [we] should adopt different methods of adjustment. Currently, attention is mostly centered on the industrial sector, in a bid to achieve energy conservation and low-carbon development, neglecting the other sectors that also constitute a substantial proportion of total final energy consumption, such as the residential and transportation sectors. Energy conservation in the industrial sector depends on technological innovations and improvements, and require comparatively stronger national regulations and inspections, while energy conservation in the residential sector requires proper guidance, encouragement at the policy level,
to help citizens form a low-carbon energy consumption lifestyle, enhance citizens’ awareness [regarding environmental issues], and enhance citizens’ conservation awareness. If energy conservation in the residential sector can be appropriately implemented, it will be hugely beneficial to the nation’s overall “low-carbon development, energy conservation” [strategy]. The energy consumption structures of the transportation sectors of each nation are [largely] similar, with petroleum [products] as the main [fuel source]. Reducing cargo transport distances to the greatest extent and reducing the occurrence of unnecessary shipping will also bear important practical implications.

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