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## Classification and performance analysis of primary energy consumers during 1980–1999

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### Abstract

Five primary energy consumer classes, namely Super, Major, Big, Medium and Small, are proposed, depending on the polymodal characteristics of the frequency distribution curve of their share of the total. The total primary energy consumption and its annual additions decrease, whereas the rates increase steadily from the Super to the Medium consumers. Since the frequency distribution histogram of additional primary energy consumptions of the Medium and above consumers during 1980–1999 is a typical bell shaped curve, the additional amounts and rates are used together to evaluate the performance levels of the countries in both parameters. The most successful countries are the USA, China, South Korea, Thailand, India, Indonesia, Taiwan, Turkey and Iran. The reason why the Super consumer USA and the Major consumer China are the biggest energy markets is because they are the first two biggest economies in the world. The success of the developing Asian countries is mostly related to their economic ties with the Super consumer USA. Among the other emerging markets, Turkey's primary energy demand has grown more rapidly than that of Iran and is expected to continue growing in the future. The emerging Medium and Big consumer markets will continue to play a significant role in the world's energy sector during the first two decades of the 21st century.

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### 1. Introduction

Regional distribution of the world's primary energy consumption has never been uniform in the past. For instance, while North America consumes around 30% of the world's total primary

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energy, Africa's share remains at only 3% recently. About half of the world's total has been consumed only in North America and Western Europe together and the rest in the other five regions. On the other hand, the major energy producing regions, the Middle East, Central and South America and Africa, consume only about 13% of the world's total energy. The primary energy consumption of each country is even more scattered than their regional distribution. They range from values close to zero to 97.5 QBtu with an average of 1.74 QBtu in 1999. Such distribution patterns usually prevent us from generalizing the consumer behavior and market performances of related countries and investigating the factors affecting them.

Therefore, the aim of this paper is to first classify the countries according to their primary energy consumptions based on their frequency distribution histograms of 1999. The performances of the primary energy consumption classes in developing their demand capacity from 1980 to 1999 are also evaluated. With this purpose, the annual increase of primary energy consumptions is studied together with its rate of change. Finally, a few of the most significant factors influencing energy market performances are discussed.

The abbreviations "TPEC", "RPEC" and "APEC", which will be used throughout the paper, stand for "total primary energy consumption", "rate of primary energy consumption" and "additional primary energy consumption", respectively. TPEC denotes the total amount of primary energy consumed in a year, whereas RPEC and APEC are the annual rate of change and the amount of change in that particular year, respectively. Unless otherwise indicated, the data used in this study are obtained from the USA Energy Information Administration's (EIA) electronic data banks [1].

## 2. Primary energy consumer classes

The frequency distribution histogram of 1999 TPEC values of 219 countries is significantly irregular (Fig. 1). A total of 211 countries, out of 219, consume less than 10.0 QBtu.<sup>2</sup> Furthermore, the consumptions of 168 countries, out of the 211, are less than 1.0 QBtu, and the consumptions of 104 countries, out of the 168, are less than 0.1 QBtu. Additionally, some significant clustering occurs within certain TPEC categories, forming a polymodal curve. The values of 191 countries are less than or equal to 2.2 QBtu (Categories 1–2). A total of 13 countries are clustered within the 2.47–4.74 QBtu range (Categories 3–5), 11 countries are clustered within the 5.23–13.98 QBtu range (Categories 6–11), 3 countries are clustered within the 21.71–31.88 QBtu range (Categories 14–32) and only 1 country has 97.05 QBtu (Category 98).

The polymodal nature of the frequency distribution diagram provides sufficient data to group the countries according to their 1999 TPEC values. In order to classify, however, using the share of world TPEC rather than the TPEC itself appears to prevent the dependency on one single year. The five primary energy consumer classes, which are presented in Table 1, are: (1) *Super consumer* (greater than 25.4%), (2) *Major consumer* (between 5.6% and 8.3%), (3) *Big consumer* (between 1.3% and 3.2%), (4) *Medium consumer* (between 0.6% and 1.2%) and (5) *Small consumer* (less than or equal to 0.5%). The Small consumers may be further divided into subclasses, however the data

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<sup>2</sup> Please note that 1999 consumptions of 41 countries are given as "less than 0.01 QBtu" in EIA's list. QBtu (also called "quad") equals  $10^{15}$  Btu in customary units and approximately  $10^{18}$  J in SI units.

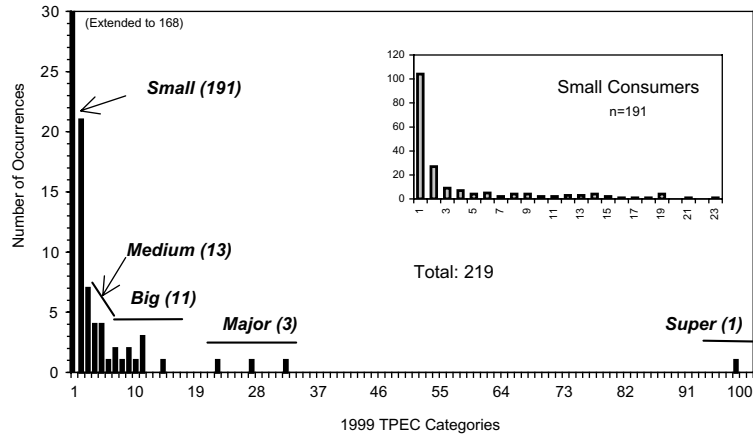


Fig. 1. Frequency distribution histogram of the world's TPEC population in 1999. Category 1: 0.0–0.9 QBtu, 2: 1.0–1.9 QBtu, and 3: 2.0–2.9 QBtu, etc. In the Small consumers, Category 1: 0.0–0.9 QBtu, 2: 1.0–1.9 QBtu, and 3: 2.0–2.9 QBtu, etc. Number of countries is given in parentheses.

Table 1  
Primary energy consumer classes; number of countries in each class is given in parentheses

| Classes     | Share of total (%) | Name of countries  |
|-------------|--------------------|--|
| Super (1)   | >25.4              | USA, EU (>16.0%)   |
| Major (3)   | 5.6–8.3            | China, RF, Japan   |
| Big (11)    | 1.3–3.2            | Germany, Canada, India, France, UK, Brazil, Italy, South Korea, Ukraine, Mexico, Spain   |
| Medium (13) | 0.6–1.2            | Australia, Iran, South Africa, Saudi Arabia, The Netherlands, Poland, Indonesia, Taiwan, Turkey, Venezuela, Argentina, Belgium, Thailand |
| Small (191) | ≤0.5               | Sweden, Egypt, Norway, United Arab Emirates, Uzbekistan, Pakistan, Malaysia, Romania, Czech Republic, North Korea, etc.                  |

used in this study do not permit this procedure (see the frequency distribution diagram of the Small consumers in Fig. 1). The ranges of this classification are also verified with BP's data with only one exception [2]. BP's data suggest that Uzbekistan falls in the Medium consumer class, whereas EIA's data suggest that the country falls in the Small consumer class.

Only the USA falls in the Super consumer class, whereas China, the Russian Federation and Japan are classified under the Major consumers. The country names of the 11 Big consumers and 13 Medium consumers are given in Table 1, and the remaining 191 countries are included in the Small consumers. Additionally, in the case when the 15 member countries are taken as a whole, the European Union is to be classified under the Super consumers with more than 16.0% share of the total. However, it should be noted that seven of the Medium and above consumer countries (Mexico, Brazil, Turkey, Thailand, China, Indonesia and India) had per capita TPECs less than the world's average in 1999. The per capita TPECs range from 29.2 QBtu (China) to 188.6 QBtu (RF) in the Major consumers, from 12.3 QBtu (India) to 417.7 QBtu (Canada) in the Big

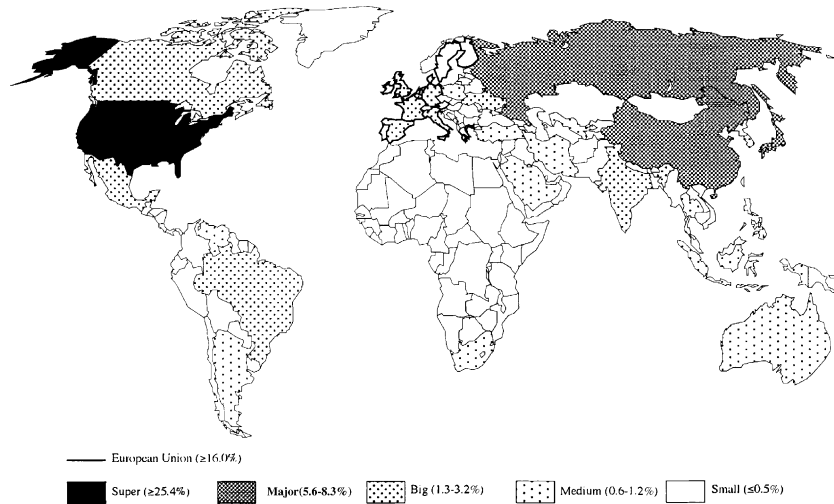


Fig. 2. Geographical distribution of the primary energy consumer classes.

consumers and from 17.9 QBtu (Indonesia) to 255.3 QBtu (Australia) in the Medium consumers. The Super consumer (USA) has a per capita TPEC of 354.9 QBtu.

The primary energy consumer classes are scattered throughout the earth surface (Fig. 2). However, the geographical distribution of the 15 Super, Major and Big consumers shows that they are all located in the northern hemisphere, with the exception of Brazil. Brazil's high energy consumption is not surprising, since it is the largest country in the southern hemisphere and has the fifth place in both the population and surface area lists in the world. Two Super consumer (including European Union) and three Major consumer countries are located between 30° and 70° north latitudes in the North American and Eurasian continents.

### 3. Performance analysis

#### 3.1. Consumer classes

The TPEC, RPEC and APEC populations of 25 of the Medium and above consumer countries are studied in detail to evaluate their achievements in developing their primary energy consumption capacities during the 1980–1999 period. Among these countries, the USA is the Super consumer, China and Japan are the Major consumers, Canada, India, France, UK, Brazil, Italy, South Korea, Mexico and Spain are the Big consumers and Australia, Iran, South Africa, Saudi Arabia, the Netherlands, Poland, Indonesia, Taiwan, Turkey, Venezuela, Argentina, Belgium and Thailand are the Medium consumers. The reason why a total of 191 Small consumer countries are not included in this study is mostly related to the incomplete nature of the available data. Additionally, three of the 28 Medium and above consumer countries are discarded because of the same reason. Among these countries, the Russian Federation and Ukraine used to belong to the former Soviet Union before 1991 and West Germany joined East Germany in 1991.

Table 2  
Ranges and averages of TPEC, RPEC and APEC of the 25 countries

| Consumer classes | TPEC (1999)  |              | RPEC (1980–1999) |           | APEC (1980–1999) |              |
|------------------|--------------|--------------|------------------|-----------|------------------|--------------|
|                  | Range (QBtu) | Aver. (QBtu) | Range (%)        | Aver. (%) | Range (QBtu)     | Aver. (QBtu) |
| Super            | >97.05       | 97.05        | 23.74            | 23.74     | 18.62            | 18.62        |
| Major            | 21.71–31.88  | 26.79        | 42.64–84.38      | 63.51     | 6.49–14.59       | 10.54        |
| Big              | 5.23–12.52   | 8.90         | 12.22–337.50     | 95.75     | 1.08–8.02        | 3.36         |
| Medium           | 2.47–4.74    | 3.58         | –24.41–384.31    | 129.07    | –1.24–3.09       | 1.58         |

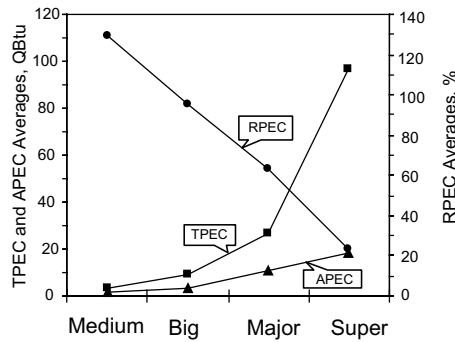


Fig. 3. TPEC, RPEC, and APEC averages of the primary energy consumer classes.

The ranges and averages of TPEC, RPEC and APEC of the analyzed consumer classes are summarized in Table 2. The TPEC averages of the consumer classes vary between 3.58 and 97.05 QBtu, the RPEC averages vary between 23.74% and 129.07% and the APEC averages vary between 1.58 and 18.62 QBtu. These data clearly show that the TPEC and APEC averages decrease, whereas the RPEC averages increase steadily from the Super to the Medium consumers (Fig. 3). This means that the performance levels in adding primary energy consumption of the high TPEC countries (Super consumers) are the highest in real values but the lowest in rates, whereas those of the low TPEC countries (Medium consumers) are the lowest in real values but the highest in rates. It should also be kept in mind that the share of the total of the Medium and above consumer countries, which used to be 65.6% with a sum of 186.78 QBtu in 1980, increased to 72.6% with a sum of 277.28 QBtu in 1999.

### 3.2. Selected countries

Neither the TPEC nor the RPEC provide sufficient information in order to investigate the performances of countries in developing their energy consumption capacities, however the APEC does [3]. The RPEC gives an idea about the countries' performances in percentages relative to a beginning point, whereas the APEC provides information on their absolute or real performances in real energy units within a time period. A country may sometimes double or even triple its consumption capacity, but the TPECs and also the APECs that are reached at the end of the same period may still be low compared to other countries. For instance, Thailand, South Korea,

Table 3

TPEC, RPEC and APEC population (1980–1999); ranks in some columns are given in parentheses

| Country      | TPEC (1999)   |                    | RPEC (1980–1999) |             | APEC (1980–1999) |                |            |                |
|--------------|---------------|--------------------|------------------|-------------|------------------|----------------|------------|----------------|
|              | Amount (QBtu) | Share of total (%) | Total (%)        | Average (%) | Minimum (QBtu)   | Maximum (QBtu) | Sum (QBtu) | Average (QBtu) |
| USA          | 97.05         | 25.41              | 23.74 (21)       | 1.25        | −3.13 (82)       | 3.65 (84)      | 18.62 (1)  | 0.98           |
| China        | 31.88         | 8.35               | 84.38 (10)       | 4.44        | −3.43 (99)       | 2.68 (94)      | 14.59 (2)  | 0.77           |
| Japan        | 21.71         | 5.69               | 42.64 (17)       | 2.24        | −0.52 (82)       | 1.13 (84)      | 6.49 (4)   | 0.34           |
| Canada       | 12.52         | 3.28               | 31.51 (18)       | 1.66        | −0.37 (82)       | 0.74 (88)      | 3.00 (8)   | 0.16           |
| India        | 12.18         | 3.19               | 192.79 (7)       | 10.15       | 0.04 (87)        | 1.41 (95)      | 8.02 (3)   | 0.42           |
| France       | 10.26         | 2.69               | 21.13 (22)       | 1.11        | −0.37 (81)       | 0.58 (91)      | 1.79 (18)  | 0.09           |
| UK           | 9.92          | 2.60               | 12.22 (24)       | 0.64        | −0.32 (81)       | 0.55 (96)      | 1.08 (21)  | 0.06           |
| Brazil       | 8.51          | 2.23               | 110.64 (9)       | 5.82        | −0.15 (81)       | 0.50 (96)      | 4.47 (6)   | 0.24           |
| Italy        | 8.04          | 2.11               | 29.89 (19)       | 1.57        | −0.17 (93)       | 0.59 (95)      | 1.85 (17)  | 0.10           |
| S. Korea     | 7.35          | 1.92               | 337.50 (2)       | 17.76       | −0.77 (98)       | 0.73 (93)      | 5.67 (5)   | 0.30           |
| Mexico       | 6.14          | 1.61               | 64.17 (14)       | 3.38        | −0.27 (83)       | 0.41 (84)      | 2.40 (11)  | 0.13           |
| Spain        | 5.23          | 1.37               | 61.92 (15)       | 3.26        | −0.15 (90)       | 0.37 (97)      | 2.00 (13)  | 0.11           |
| Australia    | 4.74          | 1.24               | 71.74 (12)       | 3.78        | −0.03 (83)       | 0.33 (97)      | 1.98 (14)  | 0.10           |
| Iran         | 4.67          | 1.22               | 195.57 (6)       | 10.29       | −0.09 (81)       | 0.49 (97)      | 3.09 (7)   | 0.16           |
| S. Africa    | 4.39          | 1.15               | 60.81 (16)       | 3.20        | −0.26 (89)       | 0.39 (97)      | 1.66 (19)  | 0.09           |
| Saudi Arabia | 4.34          | 1.14               | 161.45 (8)       | 8.50        | −0.05 (82)       | 0.36 (81)      | 2.68 (9)   | 0.14           |
| Netherlands  | 3.85          | 1.01               | 20.69 (23)       | 1.09        | −0.21 (81)       | 0.19 (91)      | 0.66 (23)  | 0.03           |
| Poland       | 3.84          | 1.01               | −24.41 (25)      | −1.28       | −0.95 (90)       | 0.56 (97)      | −1.24 (25) | −0.07          |
| Indonesia    | 3.60          | 0.94               | 224.32 (3)       | 11.81       | −0.18 (98)       | 0.33 (93)      | 2.49 (10)  | 0.13           |
| Taiwan       | 3.52          | 0.92               | 214.29 (4)       | 11.28       | −0.05 (81)       | 0.25 (95)      | 2.40 (12)  | 0.13           |
| Turkey       | 2.95          | 0.77               | 197.98 (5)       | 10.42       | −0.10 (94)       | 0.27 (96)      | 1.96 (15)  | 0.10           |
| Venezuela    | 2.80          | 0.73               | 76.10 (11)       | 4.01        | −0.07 (83)       | 0.14 (86)      | 1.21 (20)  | 0.06           |
| Argentina    | 2.71          | 0.71               | 65.24 (13)       | 3.43        | −0.08 (85)       | 0.21 (86)      | 1.07 (22)  | 0.06           |
| Belgium      | 2.61          | 0.68               | 29.85 (20)       | 1.57        | −0.11 (82)       | 0.19 (96)      | 0.60 (24)  | 0.03           |
| Thailand     | 2.47          | 0.65               | 384.31 (1)       | 20.23       | −0.13 (98)       | 0.38 (95)      | 1.96 (16)  | 0.10           |
| Total        | 277.28        | 72.61              |                  |             |                  |                | 90.50      |                |

Indonesia, Taiwan and Turkey have the five highest RPECs, whereas the USA, China, India, Japan and South Korea have the five highest APECs (Table 3). On the other hand, the USA, France, the Netherlands, the UK and Poland have the five lowest RPECs, and the UK, Argentina, the Netherlands, Belgium and Poland have the five lowest APECs. The minimums and maximums of the TPECs, RPECs and APECs occur in Thailand and the USA, in Poland and Thailand and in Poland and the USA, respectively.

In contrast to the world's TPEC population in 1999 (Fig. 1), the frequency distribution curve of the 25 countries' APEC population between 1980 and 1999 is typically bell shaped, representing a normal distribution (Fig. 4). The APECs vary from −3.43 QBtu (China in 1999) to 3.65 QBtu (USA in 1984) with an average of 0.19 QBtu. Among the 475 values, 378 are positive with a sum of 112.77 QBtu, and 94 are negative with a sum of −22.27 QBtu, resulting in an overall sum of 90.50 QBtu. The frequency distribution curve is slightly right skewed between Category 1, ranging

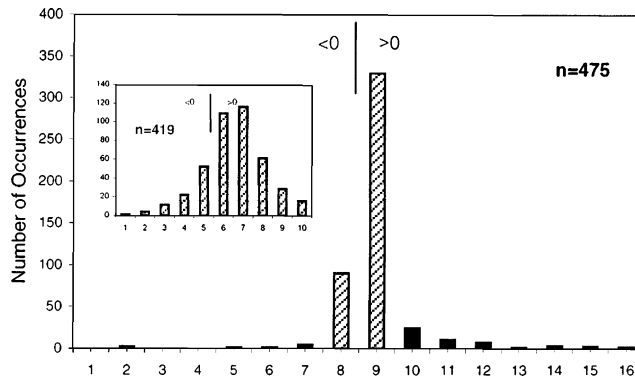


Fig. 4. Frequency distribution histogram of the 25 countries' APEC population (1980–1999). Category 1: from  $-3.5$  to  $4.0$  QBtu, 2: from  $-3.5$  to  $-3.0$  QBtu, 3: from  $-3.0$  to  $-2.5$  QBtu, etc. The inset gives the details of Categories 8 and 9 (hatched areas). Category 1: from  $-0.5$  to  $-0.4$  QBtu, 2: from  $-0.4$  to  $-0.3$ , 3: from  $-0.3$  to  $-0.2$  QBtu, etc.

from  $-3.5$  to  $-4.0$  QBtu and Category 16, ranging from  $+3.5$  to  $+4.0$  QBtu. The highest and also average frequencies occur in Category 9, ranging from  $0.0$  to  $+0.5$  QBtu, and the second highest frequency occurs in Category 8, ranging from  $0.0$  to  $-0.5$  QBtu. The total frequency of these two categories is 419, which consists of about 88.21% of the overall population. Their frequency distribution is more symmetrical than the overall distribution as shown in the inset in Fig. 4. The maximum frequencies occur in Category 7, ranging from  $+0.1$  to  $+0.2$  QBtu, and in Category 6, ranging from  $0.0$  to  $+0.1$  QBtu, in this diagram. The average is also located in Category 7. These two categories consist of about 47.37% of the 475 data.

Since the frequency distribution histogram of the APEC population does not permit a meaningful grouping, the APEC average–RPEC average diagram, in which the effects of both parameters are reflected, appears to be the best way to measure the performance levels of the countries during the studied period (Fig. 5). Because the sum of the APECs of the 25 countries

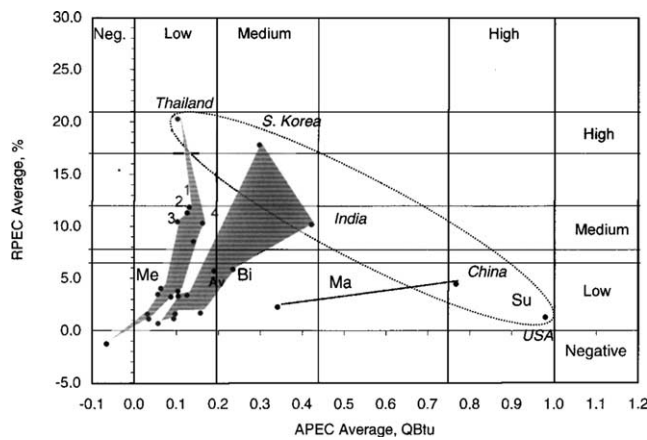


Fig. 5. APEC average–RPEC average diagram. Shaded areas indicate the consumer classes (Su: Super, Ma: Major, Bi: Big, Me: Medium consumers). 1: Indonesia, 2: Taiwan, 3: Turkey, 4: Iran, Av: Average. Inside the dotted area are the top energy markets.

consists of 93.3% of the world's total, these countries can be taken to represent the world. The frequency distribution of the APEC averages suggests a four fold subdivision as high, medium, low and negative. The countries with high APEC averages are the USA (0.98 QBtu) and China (0.77 QBtu), while the medium APEC average countries are India (0.42 QBtu), Japan (0.34 QBtu), South Korea (0.30 QBtu) and Brazil (0.24 QBtu). The third group consists of the remaining 25 countries, for which the APEC averages vary between 0.03 and 0.16 QBtu. The only negative value, which belongs to Poland, is placed in the last group. The Super and Major consumer countries have high and medium APEC averages, the Major and Big consumer countries have medium APEC averages, the Big and Medium consumer countries have low APEC averages and one Medium consumer country has a negative APEC average.

Similarly, the frequency distribution of the RPEC averages also suggests that four groups, as high, medium, low and negative, occur. The high RPEC average countries are Thailand (20.23%) and South Korea (17.76%), and the medium RPEC average countries are Indonesia (11.81%), Taiwan (11.28%), Turkey (10.42%), Iran (10.29%), India (10.15%) and Saudi Arabia (8.50%). The remaining countries, whose values vary between 0.64% and 5.82%, are included in the low RPEC average group. The negative value of Poland (−1.28%) is in the last group. Some Big and Medium consumers have high and medium RPEC averages, whereas the Super, Major and some Big and Medium consumers have low RPEC averages. One Medium consumer has negative APEC and RPEC averages.

In short, the Super consumer countries tend to have high APEC averages but low RPEC averages, the Major consumer countries tend to have medium to high APEC averages but low RPEC averages, the Big consumer countries tend to have low to medium APEC averages but low–medium to high RPEC averages and the Medium consumer countries tend to have low APEC averages but low–medium to high RPEC averages. Since there is no country within the “high–high”, “high–medium” and “medium–high” brackets in the APEC average–RPEC average diagram in Fig. 5, the most successful countries in both parameters appear to be the USA and China (low RPEC average–high APEC average), South Korea (high RPEC average–medium APEC average), Thailand (high RPEC average–low APEC average) and India (medium RPEC average–medium APEC average). However, Indonesia, Taiwan, Turkey and Iran may also be included in the high RPEC average countries, since they are located very close to the upper boundary of the medium RPEC average group. Within the top energy markets, the USA and China are the biggest markets, whereas South Korea, Thailand and India (and also Indonesia, Taiwan, Turkey and Iran) are the emerging markets.

#### **4. Discussion and conclusions**

The World Energy Council identified the key drivers shaping global energy supply and its use as population growth, economic and social development, financial and institutional conditions, local/regional and global environmental concerns, efficiency of energy supply and use, technological innovation and development and access to sufficient modern energy in the developing countries [4]. However, in most of the equations used for energy modeling, primary energy demand is basically accepted to be a function of economic activity and end user prices (e.g. Ref. [5]).

Economic growth is accepted as the most important driver of primary energy demand because a nearly linear relationship exists between the demand and GDP in market economies, especially after 1982 (e.g. Refs. [4,5]). The reason why the Super consumer USA and the Major consumer China are the “top energy markets” is, hence, obvious. The USA is the largest economy in the world and produces more than one fifth of the world’s and close to 40% of the OECD’s economic output [5]. Similarly, the world’s most populous country, China, is the second largest economy in the world after the United States. China, which is now ranked 11th, is expected soon to be among the world’s top 10 trading economies.

The USA’s share of the world’s primary energy consumption has always been the highest among other countries, reaching about one quarter of the world’s consumption for the last couple of decades. The strong correlation between the USA and the world historical APEC diagrams is another proof of the USA’s influence on the world’s energy consumption patterns. On the other hand, China is the second largest primary energy consumer behind the USA and the third largest energy producer after the USA and the RF. Additionally, the USA, which is second after Saudi Arabia in oil production, second after the RF in natural gas production and first in both oil and natural gas consumption, is by far the most significant player in the petroleum industry [6]. China, which is third after the USA and the RF in natural gas consumption and is expected to be a major importer of crude oil in the very near future, is also the world’s largest consumer of coal with about 30% of the world’s total [5].

Among the top energy markets, South Korea, Thailand, India, Indonesia and Taiwan, which are characterized by medium to high RPEC averages, are classified as “Developing Asia” by the USA’s Energy Information Administration [7]. The high performances of these emerging markets in developing primary energy demand during the studied period are related to their close ties with the Super consumer USA’s economy, since the USA is the largest export market for many of these countries. Economic recession in the USA has always had more negative impacts on these countries than the others, since it means lowered demand for imports, as is the case during 2001–2002 [7]. Among the secondarily important emerging markets, in Turkey, primary energy demand has grown more rapidly than in Iran and is expected to continue to grow in the future [8]. With its dynamic development and rapid population growth, Turkey’s performance is expected to be higher in the future than at present [3].

Energy prices are also important, since low end user prices mostly result in intense energy use. During economic growth, energy prices become the fundamental factor affecting energy use, while the impact of other factors decreases. The dominance of hydrocarbons (oil is 40% and natural gas is 25%) in today’s energy mix eliminates all doubts about the role of petroleum prices in shaping the world energy consumption patterns. For instance, the prices in 1980, which have been the highest in the history of petroleum, caused sharp decreases in TPEC and APEC in 1980 and 1981. The EIA has estimated that world oil prices will reach \$25 per barrel in 2000 dollars (\$42 per barrel in nominal dollars) at the end of 2020 [7]. This is about double the price band the Organization of Petroleum Exporting Countries has defined as its preferred range at present. However, it should also be kept in mind that the fastest growing fossil fuel in at least 20 years is usually projected to be natural gas not oil.

Many forecasters expect, in reference scenarios, the world primary energy demand to grow by around 2% annually during the next 20 years (e.g. Refs. [4,7,9,10]). This is about 0.4% more than the average rate during the last two decades. However, developing countries are projected to

account for 60% of the world's total primary energy demand compared to the developed countries' 30% for the same period, although per capita energy consumption will remain much lower in developing countries [7,11]). Therefore, the emerging Medium and Big consumer markets, in which the energy demand is projected to grow on an average of 4% annually, seem to continue to play a significant role in the world's energy sector for at least two decades into the 21st century.

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