

TECHNICAL ARTICLE

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# Energy efficiency and conservation indicators in Yemen

Ali M. Al-Ashwal

## Abstract

In this paper we assess energy conservation and analyse energy efficiency in various sectors in Yemen. Accordingly, the paper introduces Yemen energy profile, energy resources and performs calculations of a number of energy indicators for different sectors. Country-specific socio- economical characteristics are presented. The concerned energy indicators covered the following: macro level indicators and indicators of energy transformation, industry, tertiary, residential, transport, agriculture and fishing sectors. For each sector 8–12 indicators were calculated. For instance the macro level indicators include: energy dependency, intensity of primary energy, intensity of final energy, ratio of final energy consumption to primary energy, ratio of final energy bill to GDP, average emission factor, intensity of CO<sub>2</sub>, average primary energy consumption per habitant, average electricity consumption per habitant. Similarly other sectors have their relevant indicators. In total 50 indicators were calculated for a period of 7 years, 2003–2009. The results of calculations are discussed and analysed. The paper has shown the high potentials of Renewable Energy Resources. Further it was shown how low the energy efficiency and energy consumption in this country are. Finally the Paper has shown also that energy dependency is reaching zero soon and within few years can be positive which shall make the country in a difficult economical challenge due heavy subsidies on energy sector and expected increase of energy consumption. Here one can see the value of this work as an initial step to help in the development of an energy strategy for Yemen.

**Keywords:** Energy conservation, Energy efficiency, Energy indicators, Energy intensity

## Introduction

This work is a summary of the main of Yemen's contribution to a regional Middle East and North Africa (MENA) project titled "Energy Efficiency Indicators". The project covered ten countries and started January 2011. The final Report was published on October 2012 [1]. The political unrest which erupted in many of the participating countries had led to delays in finalising the project.

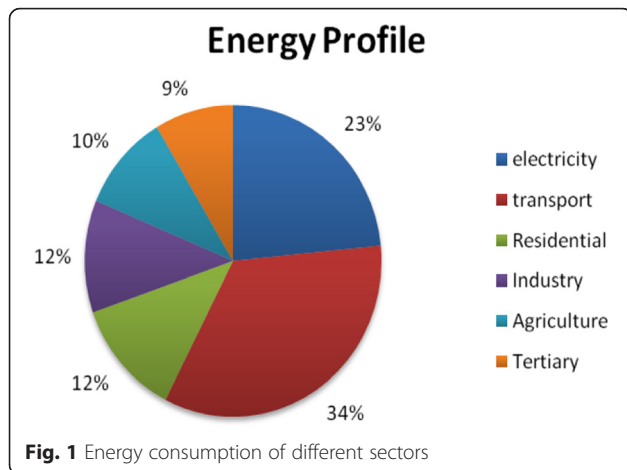
The political unrest and lack of a National Data Bank has made the data collection phase very tedious. Nevertheless the data availability has reached more than 63 % which provides a sufficiently good basis to perform the study. Accordingly the indicators were calculated and the work was performed.

Since human activity is heavily dependent on energy usage and generation, energy indicators have long been used as a measure of a society's development and

sustainability. For example, in 1996 the United Nations Department for Policy Coordination and Sustainable Development compiled over 130 indicators [2]. Such a large set can provide an accurate way to assess different aspects of sustainability and development [3–6].

This paper introduces Yemen's energy profile and energy resources. The energy profile shows that the transportation sector is the largest consumer of energy. Next, energy resources are presented, oil is the main source but its production has declined. On the other hand, gas is a promising resource and renewable energy resources have a very high potential. Then the paper presents and analyses a number of energy indicators in Yemen. Both macro level indicators and those for different sectors are discussed in order to assess energy conservation and find out energy efficiency in various sectors. Some of the indicators used are defined and the method to calculate them is presented in Appendix. To assist in the analysis country-specific socio-economical characteristics are presented. The energy indicators covered the following: macro level

Correspondence: ali.alashwal@ye.liu.edu.lb  
Department of Electrical Engineering, School of Engineering, Lebanese International University (LIU), Sana'a Campus, Sana'a, Yemen



indicators and indicators of energy transformation, industry, tertiary, residential, transport, agriculture and fishing sectors. For each sector 8–12 indicators are calculated.

In total 50 indicators were calculated covering a period of 7 years, 2003–2009. The civil unrest which started end of 2010 early 2011 has made it difficult to extend the analysis beyond 2009. The results of the calculations are discussed and analysed. The paper has shown that both energy efficiency and consumption are extremely low in Yemen. Finally, the paper shows also that energy dependency is reaching zero soon and within few years can be positive which shall make the country in a difficult economic situation due to heavy subsidies on energy sector and expected increase of energy consumption. Here one can see the value of this work as an initial step to help stakeholders of the sector to develop rational *energy strategy for Yemen*.

**Energy profile and energy resources**

**Energy profile**

Energy demand was in 2009; 7423 thousand ton oil equivalent (ktoe) [7, 8]. This demand is met by local production

and imported oil products of 4550 ktoe. However, Yemen exports crude oil and natural gas which reached 12,694 ktoe in 2009. Figure 1 shows the energy profile of the country. The grand total of energy production in 2009 reached 15,567 ktoe. The transport sector was accounted for 34 % of the consumption (most consumption), while minimum consumption was due to the tertiary sector. The profile structure can be explained by the fact that only 70 % of the country is covered by electricity, tourist industry is not strong due to the high security risk and biomass is not included in residential consumption.

**Energy resources**

The energy resources in Yemen consist of the following:

1. Oil [2]: It is the main source of energy. Yemen has been exporting oil since the nineteen eighties. The amount of produced crude oil reached 400,000 barrel/day in nineteen nineties but in 2009 it was 284 barrel/day.
2. Gas [2]: Currently, the certified gas reserved is 18.215 tcf. From this amount 9.5 tcf is allocated for export. The rest can be used for domestic needs or for export.
3. Renewable Energy Resources: They have a high potential. A study carried out by the Consultants Lahmeyer International, Germany assessed these potentials and had the following findings [9]:
  - a. Wind: preliminary estimates showed that around 14,214 MW could be developed at assessed windfarm sites. Economically attractive sites were those with more than 3500 full load hours per year. A capacity of around 2507 MW could be developed at these sites which could generate around 8293 GWh of electricity per year.
  - b. Solar: The annual average solar insolation in Yemen ranges from 5.2 to 6.8 kWh/m<sup>2</sup>/day. The resource assessment study estimated a

**Table 1** Macro-level indicators

Abb	Indicators	Unit	2003	2004	2005	2006	2007	2008	2009
EDR	Energy dependence ratio	%	-417 %	-438 %	-300 %	-286 %	-168 %	-135 %	-110 %
IPE	Intensity of primary energy	toe/10 <sup>6</sup> YR	2.01	1.85	2.34	2.12	2.55	2.56	2.72
IFE	Intensity of final energy	toe/10 <sup>6</sup> YR	1.54	1.43	1.81	1.66	1.98	2.01	2.13
RFEPE	Ratio of final energy consumption to primary energy	%	77 %	77 %	77 %	78 %	78 %	78 %	78 %
REB	Ratio of national energy bill to GDP	%	8 %	9 %	13 %	12 %	14 %	16 %	11 %
RPSE	Ratio of public subsidies for energy to GDP	%	0.07 %	0.21 %	0.73 %	1.1 %	1.5 %	3 %	3.6 %
AEF	Average emission factor	teCO <sub>2</sub> /toe	3.06	3.05	3.03	3.02	3.02	3.00	3.00
ICO2	Intensity of CO2	teCO <sub>2</sub> /10 <sup>6</sup> YR	6.15	5.65	7.09	6.40	7.71	7.68	8.16
AECH	Average primary energy consumption per habitant	ktoe/10 <sup>3</sup> hab	0.218	0.203	0.263	0.241	0.296	0.300	0.325
AELCH	Average electricity consumption per habitant	MWh/hab	0.143	0.149	0.162	0.173	0.190	0.203	0.203

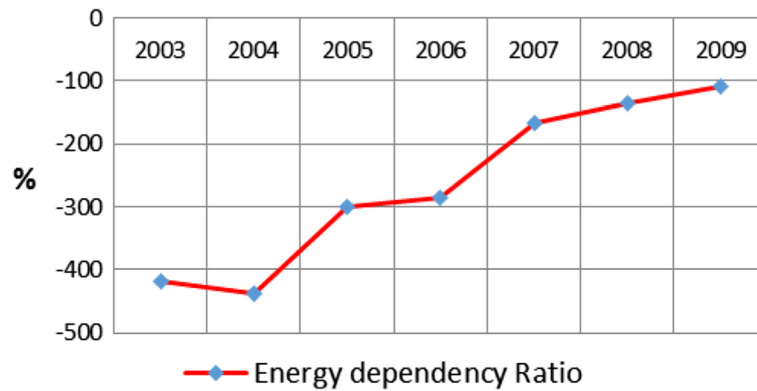


Fig. 2 Energy dependency ratio

technical potential for different applications, e.g. solar heating, photovoltaic and solar thermal, that could reach 2210 MW.

- c. Geothermal: Yemen is situated near three tectonic boundaries which are among the most active in the world, viz. the Gulf of Aden, the Red Sea and the Eastern African Rift System. These three tectonic plates meet in a triple junction creating high geothermal gradient, and subsequently geothermal energy potential was estimated to be 28.5 GW.

**Yemen circumstances affecting energy indicators calculation**

Yemen has specific factors affecting calculation results of energy indicators. These factors are listed below:

- 1) Electricity and oil products are heavily subsidised, the subsidies reached around US\$2.7 Billion in 2014.

This is approximately 6 % of the GDP. This situation affects Energy Intensity Indicators. For example, energy intensity could be high because the fuel is cheap, see Appendix Table 10.

- 2) Shortage of power generation to meet demand is estimated to be 1200 MW. This shortage is around 30 %. In addition, more than 30 % of the country territory is not covered by electricity supply and many industries have their own power station which are not connected to the national grid. Therefore, the average electricity consumption is very low.
- 3) Biomass (wood, firewood and/or charcoal, dang, etc.) has substantial participation in rural household energy consumption. This form of energy is not recorded and varies from 1 year to another depending on some factors such as liquid petroleum gas (LPG) availability, rainfall and unemployment in rural areas.
- 4) Yemen’s GDP is considered to be very low. According to the IMF [4] Yemen’s GDP per capita

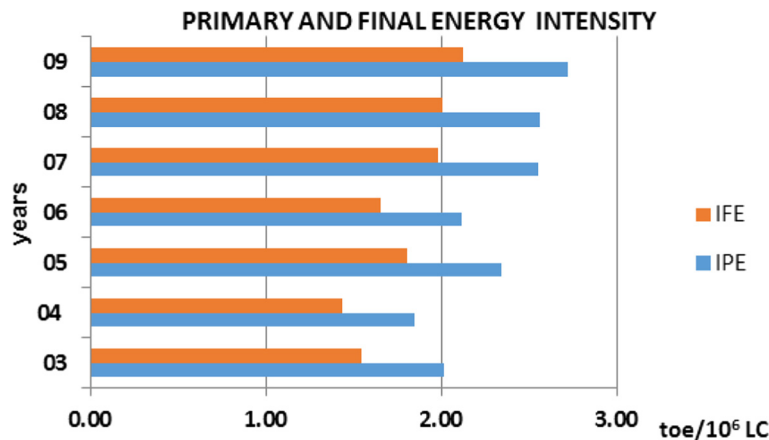
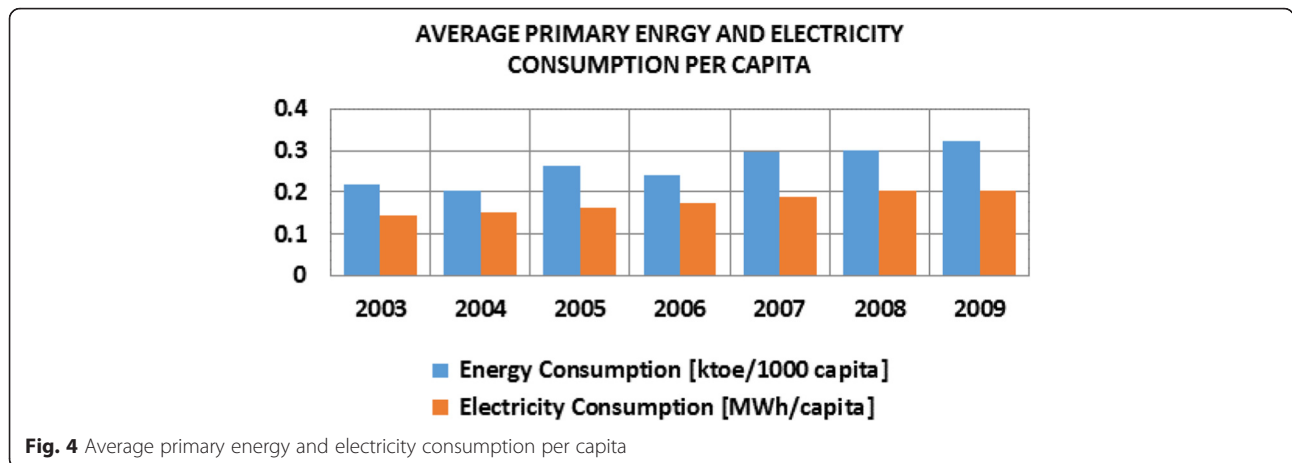


Fig. 3 Primary and final energy intensity



in 2009 was USD 2475 and it was ranked 137 in the world, due to the political instability since 2011 the GDP has been dropping.

**Indicator analysis**

**Data collection and main sources of data**

Appendix shows basic formulas for calculation of those indicators which require further clarification. In order to calculate the indicators, the necessary data had to be collected. During data collections a number of difficulties were faced some of which are listed below:

- Access to data sources is not easy, moreover some data is considered secret.
- The political unrest since 2011 has limited the data availability for these years.
- There are no sector specific data.
- There is no data history.
- The available data contains discrepancies.
- Complex routine and bureaucracy in all ministries and even private sector entities.
- Involvement of various entities in the same task, for example transport sector.
- The existing databases have limited capacity and capability and lack of MIS.
- Unfortunately in Yemen there is no National Data Bank.

In order to comprehensively carry out the task many sources were used, mainly:

**Table 2** Electricity generation and consumption

	Units	2003	2004	2005	2006	2007	2008	2009
Consumed electricity	ktoe	235	253	283	312	351	387	399
Generated electricity	ktoe	355	375	410	459	519	563	581

- Yearly Statistical Book [7].
- Records of many ministries, entities, corporations and organization concerned in energy [10–15].
- Records of some international agencies [16].

**Macro-level indicators**

Macro-level indicators are concerned with the country’s energy status and its impact on the economy, social development and the environment. The importance of macro-level indicators of energy of a country comes from the fact they reflect its level of economic and social development. In addition, macro-level indicators expose other aspects such as environmental issues and energy efficiency. The formulas need to calculate these indicators are presented in Appendix Table 10. In this study the macro level indicators include:

- Energy dependency, which is related to energy import/export status and is an indicator of a country’s dependency on energy imports.
- Intensity of primary energy, intensity of final energy and ratio of final energy consumption to primary energy. These three indicators are related to energy efficiency as explained [6].
- Ratio of final energy bill to GDP, which is related to the country economy.
- Average emission factor and intensity of CO<sub>2</sub>. These two indicators are related to environment.
- Average primary energy consumption per inhabitant and average electricity consumption per inhabitant which are social indicators.

**Table 3** Yearly Petroleum product production

Product	LPG	Naphtha	Kerosene	Gasoline	Diesel	Fuel oil	Asphalt
Million Ton	50,144	59437	533,197	918,271	918,105	571,308	925,38

**Table 4** Indicators of energy transformation

Abbreviation	Indicators	Unit	2003	2004	2005	2006	2007	2008	2009
SREC	Share of installed renewable energy electricity capacity	%	0 %	0 %	0 %	0 %	0 %	0 %	0 %
URIC	Usage rate of the installed power generation capacity	%	47 %	45 %	49 %	54 %	59 %	61 %	50 %
AETS	Apparent efficiency of energy transformation sector	%	78 %	77 %	78 %	75 %	77 %	74 %	74 %
PGEFF	Power generation efficiency of thermal plants	%	30 %	31 %	32 %	32 %	33 %	33 %	33 %
SCFFP	Specific consumption of thermal power plants	toe/GWh	283.1	281.1	270.1	265.7	259.1	258.6	263.2
PGF	Power generation efficiency	%	30	31	32	32	33	33	33
SCPG	Specific consumption of power generation	toe/GWh	283.1	281.1	270.1	265.7	259.1	258.6	263.2
TDEE	Transmission and distribution electricity system efficiency	%	78 %	80 %	83 %	82 %	83 %	83 %	85 %
PGEF	Power generation emission factor	teCO <sub>2</sub> /GWh	821	815	783	770	751	750	763
ESEF	Electricity sector emission factor	teCO <sub>2</sub> /GWh	1169	1142	1006	999	965	950	951

From Table 1 and as shown in Fig. 2 one can see that first indicator energy dependence ratio (EDR) was -417 % in 2003, but in 2009 it climbed to -110 % which means that Yemen was independent in its energy resources until 2009. Furthermore, Yemen exports energy products (oil and gas). However, since the EDR indicator is increasing rapidly, one could conclude that Yemen could go into energy dependency phase within few years.

The second and third indicators are related to intensity of primary and final Energy (IPE & IFE<sup>1</sup>) which have small values not due high efficiency but because the energy consumption is comparatively low, the results are summarised in Fig. 3.

It is worth examining the fifth indicator, i.e. Ratio of National Energy Bill to GDP. The significant growth in this indicator is deemed a great challenge for Yemen. Thus it is essential for the State to reform its fuel subsidy policy.

Unitary energy and electricity consumption indicators show low levels compared to other countries which reflect the overall low level of economic development in Yemen. In addition, they indicate that high

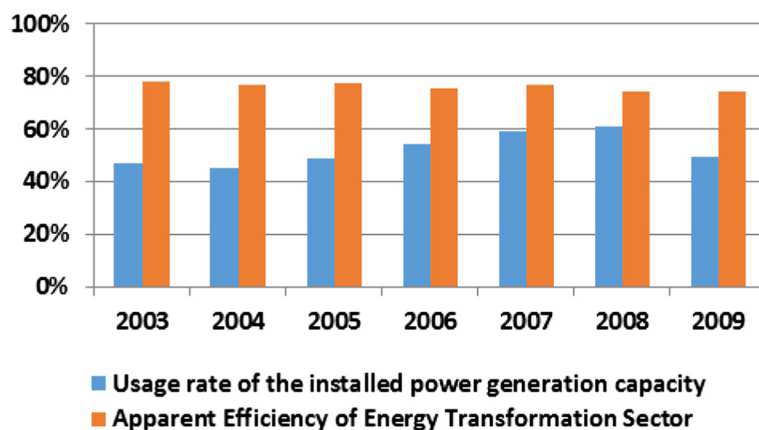
demand for energy should be expected in the future as development programs are implemented. The results are summarized in Fig. 4.

**Energy transformation sector indicators**

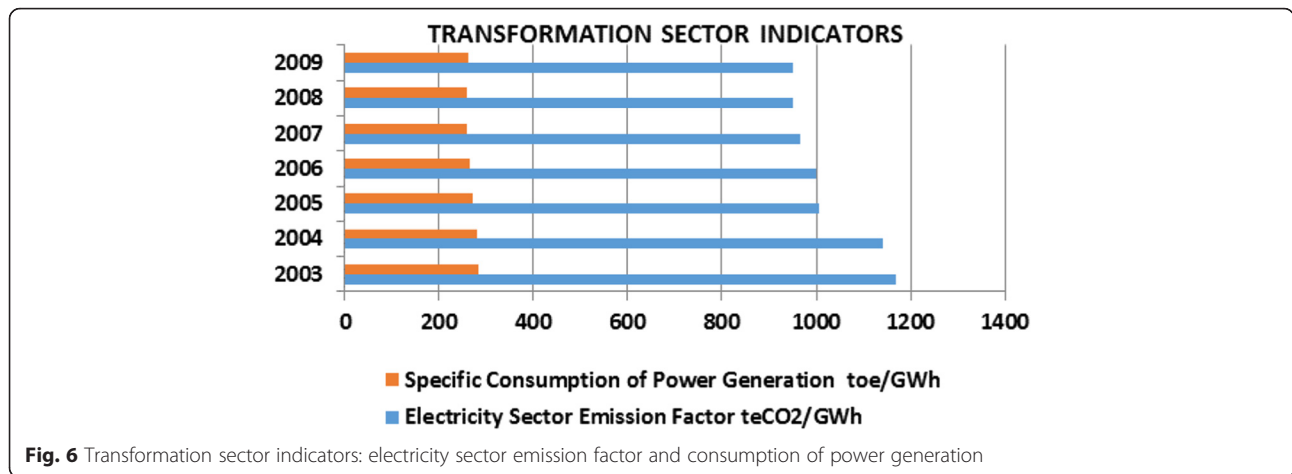
Energy transformation sector is related to all forms of energy conversion. In Yemen it includes all forms of electricity generation and oil refinery. Formulas to calculate these indicators are defined in Appendix Table 11.

Electricity sector suffers from serious problems, mainly: shortage of available generating capacities to meet demand, low efficiency as shown in Table 2, low coverage of supply, low reliability, bad quality of services and mismanagement. The Sector needs to be reformed and the investment plans must be implemented.

In Yemen there are two oil refineries. One was installed in Aden when it was British Colony, in the middle of last century. The monthly average crude oil refined in Aden Refinery is 2.161 MMbbls. The yearly production profile is shown in Table 3.



**Fig. 5** Apparent efficiency of energy transformation sector



The other oil refinery is located in Mareb which was installed in the nineteen eighties. The monthly average of crude oil refined in Mareb Refinery is 250,000 bbls, i.e. around 10 % of the capacity of Aden refinery and having almost the same spectrum of oil products.

The Table 4 presents the main indicators calculated for transformation sector. The zero share of renewable energy electricity capacity indicator (SREC) shows that renewables are not utilized in spite of their high potentials (SREC) as discussed in section Energy resources.

Usage rate of the installed power generation capacity (URIC) indicator reflects power station availability and utilization. It ranges between 47 and 61 %, which is significantly low. Noticeable sharp reduction of this indicator in 2009 is due to the fact that the Public Electricity Corporation (PEC) started in this year electricity purchase from private electricity producers.

Apparent efficiency of energy transformation sector (AETS) indicator, Fig. 5, generally expresses whole energy efficiency. It ranges between 78 and 74 %, which is quite low. This fact should encourage concerned entities to work out initiatives to improve the efficiency.

Generation Emission (PGEF) indicator shows slight improvement in the emission reduction factor. However this indicator is still high compared to similar countries in the region. Specific Fuel Consumption (SCFFP) indicator shows a reduction in fuel consumption up to 2008. In 2009 it slightly increased possibly due to power shortage increases which led to the running of the thermal plants with lower efficiency.

Indicators PGF and SCPG are replica of PGEFF & SCFFP indicators respectively, because power generation types in Yemen is limited to thermal power stations, see Fig. 6.

**Industrial sector indicators**

Industrial sector in Yemen is still at a low level of development, as the contribution of the industrial sector in the GDP for 2009 was around 24 %. This fact is clearly seen from the amount of energy consumed by the industry sector which reached 15.2 % (881 ktoe) of final energy consumption in 2009 year. Industries like steel and new cement plants were commissioned in 2011. But other heavy industries do not exist.

Final energy intensity for industry is given by final energy consumption of industry sector divided by added value at a constant price. One can see that the intensity almost doubled between 2003 and 2009. But this increase occurred due to less increase rate of value added of the sector. Specific consumption for cement seems to be within the average in similar countries. The results are summarised in Table 5.

**Tertiary sector indicators**

Due to unavailability of most of data for this sector, the indicators were not calculated except Energy Intensity which is defined as the final energy consumption of the tertiary sector divided by the tertiary sector added value at constant price, as shown in Table 6. Here we notice slight increase in energy intensity because value added increasing was less than energy consumption which indicates less efficiency.

**Table 5** Industrial sector indicators

Abbreviation	Indicators	Unit	2003	2004	2005	2006	2007	2008	2009
BSEC	Specific energy consumption for cement	toe/t	0.101	0.099	0.115	0.103	0.110	0.110	0.109
FEIS	Final energy intensity of industry sector	toe/10 <sup>6</sup> YR	5.335	5.086	6.548	6.233	7.977	8.358	9.120

**Table 6** Tertiary sector indicators

Year		2003	2004	2005	2006	2007	2008	2009
Energy intensity	Toe/10 <sup>6</sup> YR	2.66	2.43	2.91	2.72	3.18	3.23	3.36

**Residential sector indicators**

The fact that around 40 % of the electricity output of distribution is consumed by household customers makes the residential sector of paramount importance. However, the number of dwellings using electricity supply represents less than 70 %. In order to meet the inhabitants’ demands for lighting, cooking, heating, cooling and other residential activities. This sector consumes other forms of energy, such as gas, kerosene, wood and biomass in addition to electricity. From Table 7 the following observations can be made:

- ❖ The unit consumption of energy (kgoe/Dw) indicator is generally low but its average increase rate is high, almost 6 % per year. The low level is explained by the low economic development of the country.
- ❖ Electricity consumption of household indicator is also low but its average increase rate is high, almost 4.8 % per year. It should be noticed that during these years and up to now there is severe power shortage. Which resulted in daily power cut-offs of at least 30 % of maximum demand. Therefore the figures shown in Table 7 are lower than what they should be.
- ❖ Energy intensity, defined as final energy consumption of the residential sector divided by household expenses at a constant price, has increased probably due to the increase in the number of households which have been connected to electricity supply.
- ❖ Although the energy products are subsidized, energy intensity indicator seems too low. This is because other forms of fuel were not included (biomass) which are used extensively in rural areas. In addition, some dwellings included in the total number may use negligible amount of energy and some may be not occupied by households.
- ❖ Air-conditioning diffusion rate shows low figures, i.e. in 100 dwells there were only 11 air-conditioners for the year 2003. This figure increased up to 12

air-conditioners for year 2009. There is number of reasons behind this result:

- Electricity Coverage is around 70 %.
- Around 70 % of dwellings are located in rural areas where this equipment is considered a luxury.
- High percentage of the population lives in the mountainous area, i.e. highlands having elevation higher than 1000 m above sea level and higher, where there is no need for air-conditioning.
- ❖ Refrigerator Indicator (ERFR), compared with other countries in the region, shows a low rate, in 1000 dwells there were only 217 refrigerators for year 2003 and 304 units for year 2009. This situation is explained partially by above mentioned reasons of air-conditioning indicator. But these rates are higher than air-condition rate because:
  - A refrigerator is considered basic need for urban household.
  - Electricity consumption of refrigerator is lower than that of air-conditioners.
  - Refrigerators are needed in all areas of Yemen.

**Transport sector indicators**

It is worth noting that the transportation sector consumed around 34 % of final energy consumption for 2009. This fact shows the importance of initiating and developing energy saving policy in this sector.

Referring to overall intensity of final energies, transport energy intensity indicator reflects the high energy consumption level of this sector (34 %). The intensity increased from 0.684 toe/Million RY in 2003 to 0.629 toe/Million YR in 2009 (see Table 8). This is more likely due the increase in the fuel price in that period. Share of household expenditure for transport indicator shows significant increase from less 16 to 19 % which negatively impacts household living quality. Motorization Rate (MR) indicator shows that the increase rate of vehicles was higher than population increase rate (see Table 8). Coupled with the very high population growth rate such a rapid increase is not sustainable.

**Agriculture and fishing sector indicators**

Agriculture and fishing sector is the most important sector for national economy because more that 70 % of

**Table 7** Indicators of residential sector

Abbr.	Indicators	Unit	2003	2004	2005	2006	2007	2008	2009
UCED	Unit consumption of energy per dwelling	kgoe/Dw	183.40	179.39	226.09	216.54	257.68	266.74	283.16
UEICD	Unit consumption of electricity per dwelling	kWh/Dw	398.78	415.80	447.32	486.02	532.88	561.83	562.52
RIPE	Intensity of residential sector	toe/Million LC	2.66	2.57	3.21	2.84	3.14	3.14	3.04
ERACR	Equipment rate of air conditioning in residential sector	Unit/Dw	0.111	0.111	0.113	0.112	0.114	0.123	0.120
ERFR	Equipment rate of refrigerator in residential sector	Unit/Dw	0.217	0.230	0.244	0.254	0.275	0.288	0.303





drop in oil production and the increase in consumption. The depletion of oil is estimated to take place within 10–15 years

- c. Low level of energy consumption and electricity consumption compared with similar countries should warn decision makers about possible significant increase in energy demand of the country in the coming years.
- d. From the above two points it is clear that the existing level of state fuel subsidies is not sustainable.
- e. Calculated low energy efficiency in different energy sectors should encourage decision makers to invest in energy conservation research and studies.
- f. This paper has shown that the fishing sector is the most economical one, which should encourage decision makers to invest in the fishing industry.
- g. The paper also can be considered as a first initiative in establishing an energy indicator framework in Yemen. Therefore it would lead to open up a wide possibility for further research works in energy sector, for instance:
  - Establish a data bank suitable for calculation of energy indicators
  - Further development of the energy indicator framework to include more indicators and continuous update of the introduced indicators.
  - Link energy indicator framework to sustainable development in Yemen
  - Link energy indicators to energy demand forecast; hence help develop country energy strategy.

**Endnotes**

<sup>1</sup>GDP constant Price 1990

**Appendix**

**Indicator calculation**

**Table 10** Macro-level indicator

No	Indicator	Unit	Formula
1	Energy dependence Ratio	%	Gross Energy Production in/ Primary energy consumption
2	Intensity of Primary Energy	Toe/YR	Primary energy consumption/ GDP at constant price
3	Intensity of Final Energy	Toe/YR	Final energy consumption/ GDP at constant price
4	Average emission factor	Te/Toe	Energy sector CO2 emissions/ Primary energy consumption
5	Intensity of CO2	Te/YR	Energy sector CO2 emissions/GDP at constant price

**Table 11** Transformation sector

No		Unit	Formula
1	Usage rate of the installed power generation capacity	%	Total generated electricity/ Total installed generation capacity
2	Apparent Efficiency of Energy Transformation Sector	%	Transformation Sector Energy Output Transformation Sector Energy Input
3	Transmission and Distribution Electricity system Efficiency	%	Total Electricity Output of the Transmission and Distribution System/Total Electricity Input to the Transmission and Distribution System
4	Power Generation Emission Factor	Te/GW	Electricity sector emissions/ Total generated electricity
5	Electricity Sector Emission Factor	Te/GW	Electricity sector emissions/ Total Electricity Output of the Transmission and Distribution System

**Table 12** Industrial sector

No		Unit	Formula
1	Final Energy Intensity of transport sector	Toe/YR	Final Energy Consumption of Transport Sector/GDP at constant price
2	CO2 intensity of transport sector	teCO2/YR	Transport sector emissions/ GDP at constant price

**Table 13** Agriculture and fishing sector indicators

No		Unit	Formula
1	Final Energy Intensity of agriculture	Toe/YR	Final Energy Consumption of Agriculture sector/Added Value of agriculture sector at constant price
2	Final Energy Intensity of fishing	Toe /YR	Final Energy Consumption of fishing sector/Added Value of fishing at constant price

### Abbreviations

AETS: apparent efficiency of energy transformation sector; Bbls: barrels; Dw: dwell; EDR: energy dependence ratio; ERF: equipment rate of refrigerator in residential sector; GDP: gross domestic product; Gwh: giga watts hour; IFE: intensity of final energy; IMF: International Monetary Fund; IPE: intensity of primary energy; Kgoe: kilo gram oil equivalent; ktoe: thousand ton oil equivalent; kWh: kilo watts hour; LPG: liquid petroleum gas; m: Metre; MENA: Middle East and North Africa Region; MMBbls: million barrels; MR: motorization rate; MW: mega watts; MW: million barrels; PEC: Public Electricity Corporation; PGEF: generation emission; RE: renewable energy; SCFFP: specific fuel consumption of thermal power plant; SREC: shared of renewable energy capacity; Tcf: trillion cubic feet; URIC: usage rate of the installed power generation capacity.

### Competing interests

The author declares that he has no competing interests.

### Author's contributions

The main contribution of this paper is that it establishes for first time an energy indicator framework in Yemen. The well-known significance of such framework for any country exposes the importance of this paper.

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