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FLOW CHART OF ENERGY WASTE IN JORDAN

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ABSTRACT
Major challenges are facing limited energy resources countries such as Jordan in trying to satisfy their national energy-demand, and simultaneously reducing negative impacts on the economy, environment, and social life. To meet the country's future energy demands, a long-term plan based on a well-defined strategy should be developed. A partnership project between Ministry of Energy and Mineral Resources, and Department of Mechanical Engineering at the Hashemite University (Jordan) is conducted to carry out research on reducing energy waste and energy consumption in the different sectors: industrial, power generation, transportation, residential, and commercial. The project consists of two main divisions: energy statistics and energy waste analysis considering all types of energy in the country. A survey is conducted to identify various systems and components which are being used by the different energy consumption processes. Energy waste and energy flow from the different sectors is modeled and presented. The study shows that the total energy waste in Jordan is about 62.7% of total national energy consumption. The major sources of energy waste are: power generation and transportation sectors followed by residential, industrial, and commercial sectors. Residential sector is found to be typical for renewable energy applications in Jordan. The effect of replacing conventional water heaters with solar water heaters is studied to show the improvement in the reduction of national energy waste, and gas emissions. This work represents the first attempt to compile a complete energy statistics in Jordan by adopting energy waste analysis in major thermal processes.

Keywords: Energy waste, Energy flow chart, National energy consumption, Jordan.

INTRODUCTION

During the past decades there was a growing interest in energy consumption from the different types of fossil fuels and its environmental and economical impacts. One method of reducing national energy consumption is by reducing energy waste from the different types of energy and power consumption systems. Energy waste analysis is a matter of importance in any energy conservation and environmental study program because it can pinpoint energy quality (grade of energy) and efficiency of energy utilization in the different thermal processes. Considering the grade of energy in each process is necessary in energy conservation planning and energy auditing [1,2]. For example, using high grade energy, such as electricity, for space heating is considered as energy waste since low grade energy such as heat from burning fuel in boiler is sufficient. Research can be directed towards areas having the main energy waste as mean for conserving energy and reducing green house gases (GHG). Energy waste analysis is vital in assessing the thermal performance of the different energy systems which play major role in the national energy auditing, gas emissions and economics analysis [3]. In Europe, for example, the German government is committed to reduce carbon dioxide emissions by 45% by the year 2020. These reduction goals can be reached only if energy conservation measures and waste energy utilization are part of the national energy policy structure [4].

The main energy sources that most countries use today are from fossil fuels. Jordan is one of those countries that may have a serious problem in energy resources and most of its energy needs is imported in the form of crude oil and petroleum products. The country experienced in the last five years a great development in the energy sector, whereas the energy demand has increased by approximately 9% annually [5]. The cost of consumed energy reached 30% of total export earnings. This is causing a huge burden on the national economy due to the lack of conventional energy resources. To face such situation it was essential to direct some efforts towards developing the existing energy system by pinpointing the sources of energy waste in the country as well as utilizing its potential indigenous sources of energy such as solar and wind power. Studies have been carried out to present energy consumption in rural and urban residential sectors in Jordan [6,7]. It was found that kerosene is the most popular fuel for space heating which represents 61% of energy consumption in residential sector. Solar-assisted heat pump system was proposed for water heating in Jordan [8]. High potential for the application of such system was found in the residential sector in Jordan. In another study on solar process heat in small factories showed good potential for Jordan [9]. Hot water or steam close to ambient pressure can be produced to supply the process heat in cloth or textile factories using small size parabolic trough collector. Fuel oil heating by a trickle solar collector was proposed by Badran and Jubran to reduce energy waste in power plants and industrial boilers [10]. Fuel oil heating process up to handling temperature between 50C to 90C may cost 5% of the energy produced from these systems and therefore applying solar energy would reduce energy waste.

In this paper energy flow in different sectors: industrial, power generation transportation, residential, and commercial was analyzed in Jordan. Energy flow charts (Sankey diagrams) are constructed considering all types of energy being utilized in the year 2001.

Energy waste and energy flow from the different sectors is modeled using spread sheet and CAD programs. Typical systems and components being used by the different energy consumption processes are identified and tabulated. Application of solar energy in residential sector was studied and proposed to replace conventional fuel systems. This study is the first attempt to compile a complete energy statistics in Jordan and it can be used as a tool for future programs in national energy projects.

SOURCES OF ENERGY IN JORDAN

Jordan has a population of about 5.1 million (in year 2001) with 3.4% population growth. The country depends mainly on imported oil for its energy needs. In the year 2001 about 4.9 million tons was imported, out of which electricity consumed about 1.8 million tons. The country has a very limited source of natural gas with a yearly production of about 220,000 tons equivalent heavy fuel oil (toe) and is completely consumed for electricity generation. Oil shale reserves are quite available (about 40 billion tons proven reserves) but not yet in use. Potential for wind and solar energies is quite available. Efforts are being made to promote electricity generation from wind and solar energies. The six main types of fuel (imported) that are being used in the country are: heavy fuel oil, diesel, gasoline, LPG, kerosene, and jet fuel as they were reported by JMEMR [5] and presented in Fig. 1. The amount of fuel consumption in the year 2001 was reached to about 0.14% of the international consumption of oil. It can be concluded from Fig. 1 that more than 65% of energy is consumed in electric power generation and transportation sectors since heavy fuel oil and diesel are used mainly in these sectors. Other types of energy sources which have promising future in Jordan are not shown in Fig.1 such as solar energy and natural gas. This figure does not show other details about the type of processes that consume each type of fuel. It is useful only for economical evaluation and statistical studies.

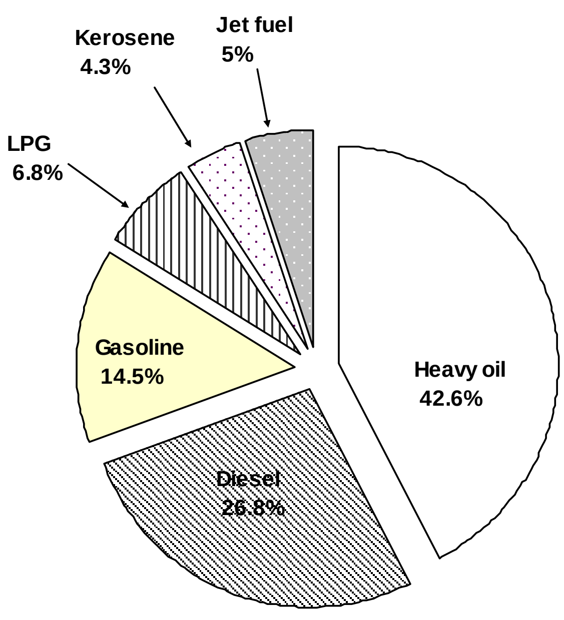

Fig.1 Energy consumption in Jordan.

ENERGY ANALYSIS IN JORDAN

National energy flow and energy waste was evaluated by adopting six types of sectors: electric power, industrial, transportation, residential, commercial, and others (such as services, and agricultural, etc.). The types of fuel used in each sector are as follows:

Electric Power Generation Sector

Most of the electric power is generated locally, however about 1.2% of electricity is imported from Egypt. The different energy sources for electric power generation sectors are: heavy fuel oil 85.4%, natural gas 11.2%, diesel fuel 1.9%, hydro power 0.22%, and wind energy 0.04%. Transition and distribution losses was estimates by Ministry of Energy and Minerals and was found equal to about 13% of the generated electricity.

Industrial sector

In this sector the energy input covers five types of energy resources: electricity at 35.3%, heavy fuel at 51.1%, diesel fuel at 11.4%, kerosene at 1.4%, and LPG at 0.8%. Electricity is used mainly in motors, lighting, and heating processes. Heavy fuel oil is used mainly in industrial boilers and furnaces. Kerosene is used in small furnaces and heaters. LPG is used in food industry ovens and heaters. Diesel is used in stationary generators and furnaces.

Transportation Sector

The types of fuel used in this sector depend on the types of engines used in the country. Petrol engines (mainly in light vehicles) represents 100% of total gasoline consumption, Diesel engines (mainly in buses, trucks, and heavy duty vehicles) consume 64.6% of diesel fuel in the country, and jet engines (used in aircrafts) consume 100% of jet fuel in the country.

Residential Sector

This sector was divided into five main parts according to the types of fuel used: electricity (34.2% of total electricity generated in the country), diesel fuel (16.9% of the country's consumption), LPG (87.2% of the country's consumption), solar energy (100% of the country's consumption), and kerosene fuel (82.7% of the country's consumption).

Commercial Sector

This sector was divided into four main parts according to the types of fuel used: electricity (33.1% of total electricity generated in the country), diesel fuel (9.7% of the country's consumption), LPG (11% of the country's consumption), and kerosene fuel (5.9% of the country's consumption).

Other Sectors

This sector consists of government offices, agricultural systems, and street lighting which cover four types of energy resources. The percentage of each type with respect to the total consumed by the country is: electricity (3.5%), diesel fuel (0.9%), LPG (2.5%), and kerosene (2.7%).

ENERGY FLOW CHART

A survey of different thermal processes in each sector was conducted by categorizing the grade of energy used in each process. In the industrial sector samples of different factories and industries were considered and types of power and energy consumption equipments (such as steam generators, boilers, furnaces, electric motors, heaters, etc.) were identified. Light industries such as: clothing, textile, paper, and food factories are dominant in this sector. Energy consumption in these industries is mainly due to low and intermediate end use heating process (hot water or low pressure steam) . In the transportation sector, samples of different types of vehicles that are used in the country (petrol, and diesel engines) were studied to estimate average performance of each. Performance of electric power generation in the country is evaluated from the generated electricity and fuel consumption in the different types of power generators given by the Ministry of Energy and Mineral Resources statistics. Energy consumption equipment which are used in residential, commercial, and others sectors are almost similar in many cases and a survey for residential equipment was found satisfactory for other sectors. A summary of energy and power consumption equipments survey and their average efficiencies in different sectors is provided in Table 1. A computer spread sheet program was constructed to perform energy flow and energy waste calculation at different processes and sectors based on converting the energy from different fuel to the unit of "ton of oil" equivalent (toe). A general form of energy flow chart was generated in CAD program environment using the results of the spread sheet as shown in Fig. 2. This figure shows energy flow and energy waste in the country for the year 2001, it also considers all types of energy used in the country including sustainable energies (solar, hydro, and wind) which are very limited and do not exceed 1.7% of the total national energy input. This energy flow chart gives a thorough indication about the national energy consumption, energy waste in different processes, and the sector that requires priority in energy conservation and auditing.

ANALYSIS OF RESIDENTIAL SECTOR

Residential sector was selected to study the possibility of replacing some conventional energy equipments with sustainable energy systems. In order to achieve this goal a survey of energy and power consumption units (such as, space air conditioning, water heating, electrical equipments) used in different location of the country was carried-out. A survey of domestic water heating which is presented in Fig. 3 shows that there are four main types of water heating systems: Electric water heater at 32%, LPG fired water heater at 26%, solar water heater at 22%, and diesel fired boiler at 20%. It can be concluded from this survey that domestic water heating represents one of the major sources of energy waste in this residential sector. This is because high grade energy (electricity) is being used in large scale (32%) in water heating while there is high potential for low grade energy application represented by domestic solar water heaters. In case of space heating the survey showed that the most common methods used in Jordan are: LPG heaters at 44%, kerosene heaters at 32%, diesel boilers at 13%, and electrical heaters at 11%.

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Table 1
Average efficiency of main processes in the country.

Fuel type	Process	Efficiency
Industrial Sector		
Heavy fuel	boiler furnaces	0.75
Diesel fuel	steam boiler heaters	0.75
LPG	Furnaces	0.6
Kerosene	Furnaces	0.65
Electricity	Electric motors (heavy duty)	0.5
Electricity	Lighting	0.5
Commercial & Service Sector		
Diesel	Boilers	0.8
LPG	ovens	0.65
LPG	space heating	0.65
Kerosene	Heaters	0.55
Electricity	electric motors	0.7
Electricity	Lighting	0.5
Residential Sector		
Diesel	water heating boilers	0.8
LPG	Ovens	0.7
LPG	space heating	0.7
Kerosene	water & space heating	0.55
Electricity	electric motors	0.5
Electricity	Lighting	0.5
Solar	Solar water heaters	0.25
Transportation Sector		
Diesel	truck & buses	0.35
Gasoline	Cars	0.25
Jet fuel	Airplanes	0.8
Others		
Diesel	boilers engines	0.55
LPG	Ovens	0.65
LPG	space heating	0.65
kerosene	space heating	0.6
Electricity	electric motors & lighting	0.5

Average daily operating hours of different types of household equipments are estimated in this survey and shown in Fig. 4. Different samples of houses at different location all around the country were selected. Number of operating hours was used to find annual energy consumption and system efficiency. Summary of average energy consumption in a typical Jordanian houses is shown in Table 2. Having the information about all energy consumption systems in this sector it was possible to construct a detailed energy flow chart using the described model that used for the entire country. The result of energy waste analysis in residential sector for the year 2001 is shown in Fig. 5. Although this figure shows good energy conversion efficiency (about 62%) compared with other sectors, there are sources of improvements in this sector such as using solar energy to avoid energy quality losses in electric water heater systems.

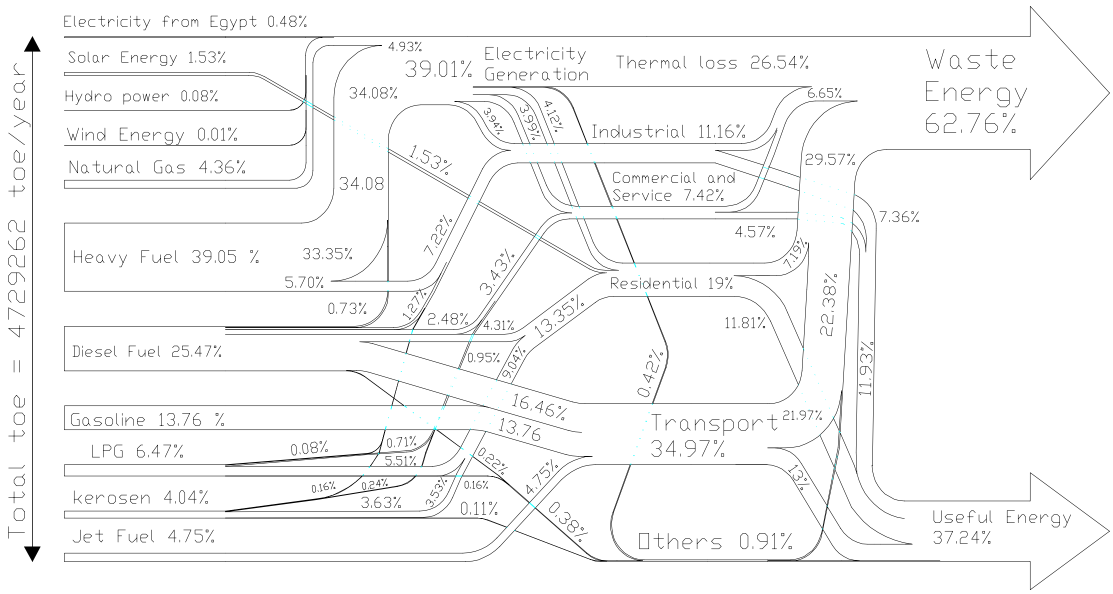

Fig.2 Types of water heating used in residential sector.

Table 2
Summary of energy consumption in a typical house

Energy	Amount	Toe/year	Efficiency	Useful (toe/y)
Electricity	340 kWh per month	0.35	0.53	0.185
Diesel	0.65 m^3/year	0.55	0.8	0.44
Kerosene	207 lit./year	0.17	0.55	0.09
LPG	0.628 toe per year	0.63	0.7	0.44

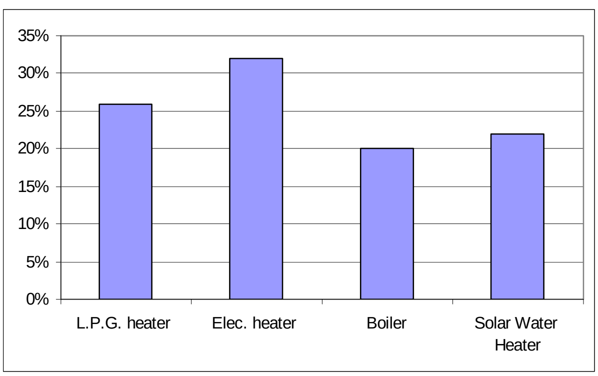

Fig. 3 Types of water heating used in residential sector.

IMPACTS OF DOMESTIC SOLAR WATER HEATING SYSTEM APPLICATION IN RESIDENTIAL SECTOR - A CASE STUDY

Jordan is blessed with very good solar energy resources. In the desert region which covers about 87% of the land, the average daily solar irradiation is about 5.5 kWh/m^2, and the annual sunshine duration is about 3000 hours [8]. Therefore, the application of solar energy in the residential sector has great potential in water and space heating systems. A case study was conducted on solar water heating (SWH) application in residential sector using RETScreen software [11] which evaluates energy production, life-cycle costs, and greenhouse gas emission (GHG) reductions for various types of renewable energy systems.

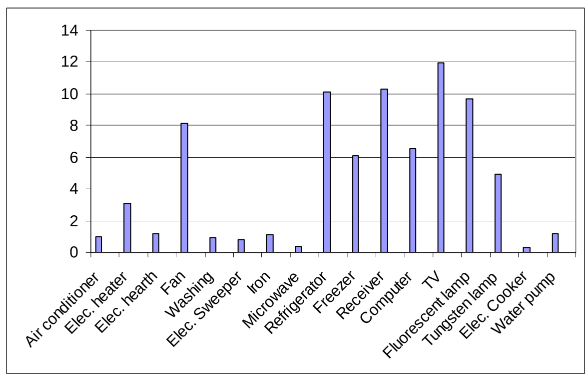

Fig. 4 Daily average operating hours of electric equipment in residential sector.

Although (SWH) is being used for more than three decades in Jordan, its application is still limited and does not exceed 25% of the water heater systems used in the country (as shown in Fig. 5). The scenario considered in this case study is to cover energy needs in domestic water heating by solar energy only. Specifications of the proposed SWH are: hot water storage tank capacity is 185L, typical water temperature is 60°C, and collector area is 5.4 m^2. The environmental impact of replacing conventional fuel water heaters with SWH is show in Fig. 6 in terms of GHG reduction (annual ton of CO_2). Maximum reduction in CO_2 is achieved when replacing electric heater with SWH due to the impact of gas emission from power generation plants. The GHG emission reduction income represents the income (or savings) generated by the sale or exchange of the GHG emission reduction credits. The estimated sum of cash that will be paid or received each year during the entire life of the proposed SWH system is shown in Fig. 7. The total annual savings are achieved due to the

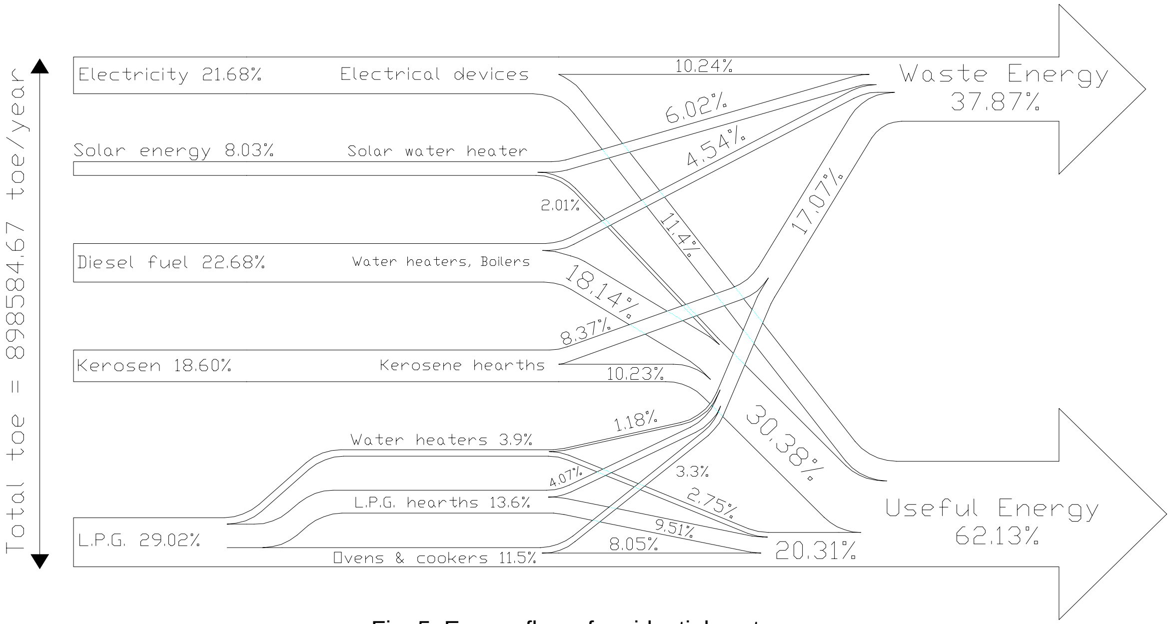

Fig. 5 Energy flow of residential sector.

implementation of SWH which cause reduction in fuel consumption and GHG emission. The payback period of SWH system depends significantly on the replaced system. In Fig. 7 the payback period of SWH which represents number of years to positive cash flow is only 5 years in case of electric water heater. Whereas replacing LPG water heater with SWH shows longer payback period (around 10 years) due to the lower unit cost of fuel and lower GHG emission.

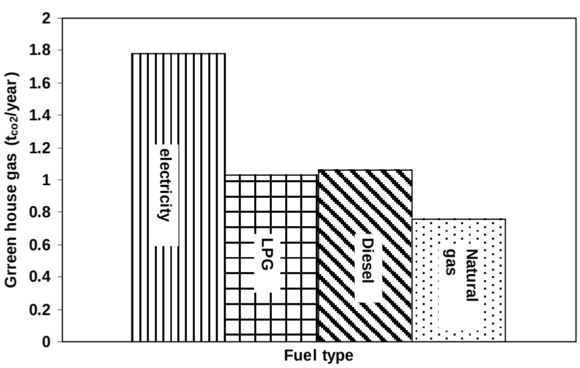

Fig. 6 Reduction in GHG emission when replacing conventional water heaters with SWH

CONCLUSION

Energy flow chart is a significant tool to pinpoint national energy consumption and energy waste. It is used to present energy conversion efficiency in different energy and power consumption processes as well as local energy situation in different sectors and sub-sectors. In this work the results of a partnership project between Ministry of Energy and Mineral Resources (MEMR) and Department of Mechanical Engineering (DOME) the Hashemite University in Jordan was presented. Energy statistic which was carried out by MEMR for the year 2001 was used by the research team at DOME to develop energy flow model. The model is used to construct energy flow chart for the different energy consumption sectors in the country. The total energy waste of the country was found equal to about 62% distributed as follows: 26% on power generation, 22% on transportation, 7% on residential, 4% on industrial, and 3% on commercial. Residential sector is found to be typical for renewable energy applications in Jordan. A case study on domestic solar water heating application in the residential sector showed crucial environmental and economical impacts. Payback period of the solar water heater in the worst case is not more than 10 years. The payback period can be reduced if lower costs SWH (manufactured locally) is considered in cost analysis.

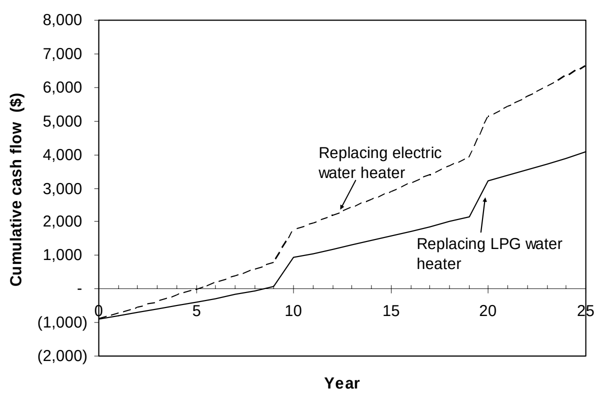

Fig. 7 Cumulative cash flow for SWH replacing electric and LPG heaters

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