Comparitive Study of Energy and Water Conservation in Domestic Gas Geysers

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ABSTRACT

Pakistan is facing the severe energy crisis by continuous increase in gap between supply and demand. Researchers associated with the field of Environmental Design & Home Economics are motivated to explore the ways to deal with current energy crisis, consumption and conservation. The research is an attempt to conserve energy and water at domestic level by comparing the performance of conventional gas geysers and instant water heaters. The study also looked at the amount of water that can be saved from instant water heaters. An experimental house had been selected where instant and conventional geysers are installed and used based on alternate week during five winter months from December 2010 to April 2011. Amount of consumed gas was observed over the peak winter time. Four control houses were also selected in the same vicinity with approx. same number of inhabitants who used conventional gas geysers. The amount of gas consumption in these houses was also observed. The amount of saved water had been calculated, based on the length of pipes from geysers to point of use and water allowed to be drained before hot water is obtained. Generally, instant water heaters are not in use locally, therefore, a questionnaire was randomly distributed to various households to know their general perception about instant water heaters.

Keywords: *Energy and water conservation at domestic level, Conventional gas geysers, Instant water heaters, Gas consumption.*

1. INTRODUCTION

The energy sector is expected to play a critical role in economic and social development of any country. In Pakistan, the economy is currently growing at a rate of over 8% by an expanding industrial sector which currently contributes 38% of the economic output and growing at a rate of 12.5%. According to Pakistan Energy Year Book (2008) total energy supplies were 62.9 MTOE (Million Tons Oil Equivalent) in financial year 2007-8 with an annual production of 28 MTOE in which gas is a dominant fuel accounting for 47.5% of Pakistan's primary energy demand, followed by oil at 30.5%, hydro at 12.2% and coal at 9.2%. Reliance on natural gas a major energy source needs to be reviewed for strategic and controlled consumption at various levels besides exploring alternate sources of energy.

Over the period demand for natural gas in Pakistan has increased by almost 10 percent annually from 2000-01 to 2007-08, reaching around 3200 million cubic feet per day (MMCFD) in 2008 against the total production of 3774 MMCFD (The Nations, 2009). Haq. (2011) mentioned that demand for natural gas exceeded the available supply with production of 4528 MMCFD gas against demand for 4731 MMCFD, indicating a shortfall of 203 MMCFD. Shahzad (2011) quoted the statement of Hagler Bailly (a global management consultant firm with an office in Islamabad) that "Pakistan is going to face gas shortage starting in 2007 and will grow every year to cripple the economy by 2025 when shortage will be 11092 MMCFD against total 13259 MMCFD productions". Based on the current trend, Pakistan's gas shortage would get much worse in the next two decades if it did not manage any alternative sources (Haq, 2010). Media has also reported the shortfall of 700 MMCFD of gas recorded by Sui Northern Gas due to increasing use of heaters and geysers (www.geo.tv).

About 18% of the population has gas connections installed at their homes and households are motivated to use gas geysers and heaters with the availability of gas (Pakistan Economic Survey, 2004-05). The conventional gas geysers are being widely used throughout the country with 25, 30 and 50 galloons storage tanks having gas fired burners to heat them. American Council for an Energy Efficient Economy (ACEEE) (2007) describes the process in which thermostat controls the temperature and automatically turns off the burner when required temperature is achieved. The amount of gas consumed by the water geysers is 1.5-2 cft/hr (cubic feet per hour) with only the pilot ignited and 30-40 cft/hr when the burner is in use. These facts indicate that careful selection of geysers can substantially reduce the gas consumption.

Jehangir and Javed (2007) claimed that water is another neglected sector in Pakistan where 38.5 million people do not have access to safe drinking water and 50.7 million people lack access to improved sanitation. The total water availability on per capita basis in Pakistan decreased from 5000 cubic meters per capita in 1951 to 2,961 cubic meters per capita in 2000 and to 1,420 cubic meters in 2005 (Government of Pakistan, 2005) and moving with an available supply of water around 1,000 cubic meters per person, which puts Pakistan in the category of a high stress country (United Nations World Water Development Report (UNWWDR), 2009). If the current trends continue, it could go as low as 550- cubic meters by 2025. Even though the per capita water availability is facing a gradual reduction, the water requirement is increasing due to population increase

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and with better living standards. The water crisis draws attention towards designing domestic appliances such as washing machines, dish washers and geysers with less consumption of water.
The conventional water heaters lead to profound wastage of this valuable resource and clean water wasted in order to obtain hot water which may pose a serious risk to the country in future. Furthermore, there is a considerable length of pipe running from the geyser to the faucets, and all this cold water stagnant in the pipe has to be drained out, resulting in a lot of water being wasted prior to availability of heated water in the faucets, this system results in the wastage of both energy and water. Taking into account water and natural gas as prime factors for our economic and social development, an attempt is made to address the energy and water conservation at domestic level. The research is carried out to explore the pros and cons of instant water heaters as there is no documented research available on the efficiency of instant water heaters in the local context. The specific objectives of the research were to asses and compare the energy consumption of conventional geysers and instant water heaters and also to ascertain the water conservation through instant water heaters.

2. WATER HEATERS

Water heating is a thermodynamic process using an energy source to heat water above its initial temperature. Generally, more than 20% of a domestic energy use comes from heating water for bathing, washing dishes, laundry and cooking (Kloub, 2005). At domestic level water is traditionally heated in vessels like water heaters, kettle, cauldrons, pots or coppers for cooking, cleaning, bathing and space heating in which temperature rate vary based on the consumption rate of hot water. Appliances for providing a constant hot water supply are known as water heaters, boilers, heat exchangers, clarifiers or geysers depending on weather they are heating portable or non portable water in domestic or industrial use. Generally, there are two categories of water heaters that are used domestically namely:

a) Tank storage water heater and
b) Tank-less water heater.

The major differences between the two are described in Box 1

2.1. Tank-Storage Water Heaters

Conventional water heaters or storage water heaters also known as geysers are the most common type of water heater in Pakistan. They are available in electric or gas models Figure 1. Klenck (1997) described detail process explaining that they contain an internal heating element which heats water to the temperature indicated on the thermostat and continuously heats the water throughout the day, whether or not it is being used and normally add up the cold water on using. Cold water must be added so that the temperature is comfortable for use.
When a hot water faucet is activated, the tank water heater is replenishing the tank with cold water at the same time, lowering the overall water temperature in the tank.

Box 1. The major differences between storage and demand water heaters.

Tank Storage Water Heaters	Tank Less Water Heaters
▪ Most Common ▪ Less Costly Than Demand Units ▪ The Highest Efficiency Storage Tank Units Show Recovery Efficiencies Of 85% And Energy Factors as High As 0.72 ▪ The High Efficiency Units Will Compare Favorably in Energy Savings to The Demand Units When the Initial Costs of The Units Are Taken into Account ▪ All Gas Combustion Units Require Basic Safety Installation Requirements.	▪ Does Not Store Hot Water ▪ Designed to Heat Water on Demand Near the Point of Use ▪ Unit Is Useful If Space Is Limited for Installing A Storage Tank Unit ▪ May Not Be Able to Serve Simultaneous Draws of Hot Water ▪ A Typical Medium Size Unit Will Raise the Incoming Water Temperatures 60 Degrees at A Rate Of 3.5 Gallons Per Minute (125,000) Btu Input ▪ Some Units Can Sense the Incoming Water Temperature and If the Incoming Water Is Already Adequately Heated, It Will Not Turn On. This Is Useful for Solar Interconnections or Circulating Systems ▪ They Are Most Often Wall Mounted and Use Vertical Venting. Limited Horizontal Venting Can Be Used

This triggers the element to draw more power to reheat the water to the desired temperature. The internal element in a gas water heater is similar to a gas stove; therefore, gas water heaters must have adequate exhaust ventilation to ensure safety. American Council for an Energy Efficient Economy (ACEEE) (2007) mentioned that storage tank water heater is continuously radiating heat loss which also contributes to the re-heating rate and energy consumption. This type of heat loss is often referred to as stand-by heat loss. By eliminating stand-by heat loss alone, energy consumption can be reduced from 20 to 30%. Due to this inefficient process a 60 gallon tank only supplies the 45 gallons of usable hot water. The other 15 gallons are lost as cold water is added to the tank during the usage process (Du Pont, 1989).

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2.2. Tank Less Water Heaters

Tank less water heaters, also called instantaneous, on-demand or instant water heaters, are popular and widely used internationally. They are compact heating units (Figure 2) that provide hot water as it is needed, and do not store hot water like conventional water heaters. When a hot water tap is turned on, water enters the tank less water heater. A sensor detects the water flow, and activates an electric or gas heating device, which quickly raises the water temperature to a preset level. When water flow stops, the heating element shuts off. Thermostatically-controlled tank less water heaters vary their output temperature according to water flow rate and inlet water temperature (Klenck, 1997). Orloff (2011) claimed that these water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil. These units are highly efficient because they do not waste energy heating a tank of water when it's not in use. It only uses energy when the hot water outlet is on and shuts down immediately when the outlet is turned off. This energy saving mechanism provides potential saving of up to 50% on water heating bills generated by conventional heaters, which keep the stored water hot, even when not being used (Du Pont, 1989). As tank less water heaters do not store a reservoir of hot water, therefore, standby losses are reduced, which makes them an energy-efficient alternative to traditional water heating. Tank less units can reduce water heating bills by 10 to 20 percent – a significant savings for homeowners. Deneen (2011) claimed that for homes that use 41 gallons or less of hot water daily, a demand heater can be 24% to 34% more energy-efficient than standard water heaters. Gas and electric tank less water heaters are available in a variety of capacities by numerous manufacturers. They can be used to meet all of a home's hot water needs. In general, gas tank less heaters have larger capacities than their electric counterparts. Some tank less units may not be able to supply enough hot water for a home that has large draws or simultaneous use of hot water. In addition, theses units have lower capacity in cold climates where more energy is needed to raise water temperature. he data obtained from the office of Sui Northern Gas Pipelines Limited (SNGPL) concluded that the thermal efficiency of tank less water heaters is 85% which is much higher than the conventional ones. It may require high rate of gas initially on ignition, and that at 20°C, correspondent to a discharge water temperature of 25°C if the inlet water temperature is 5°C. Due to the higher number of bends on the heat exchanger there is a greater heat loss in the instant water heater.

3. ADVANTAGES AND DISADVANTAGES OF TANK LESS WATER HEATERS:

A tank less water heater might cost more initially but it may result in both energy and cost savings in the long term. As water is heated only when it is needed there is no storage of hot water. Even in homes or buildings with a high demand for hot water a tank less water heater may provide some levels of savings. If instant hot water at the taps for limited hours is a priority, a recirculation system similar to those in the tank type systems can be accommodated by using an aqua stat and timer in order to decrease the added heat loss from the recirculation system. In addition to the energy savings the tank less water heaters are also capable of supplying unlimited hot water as long as the water is flowing through the heat exchanger.

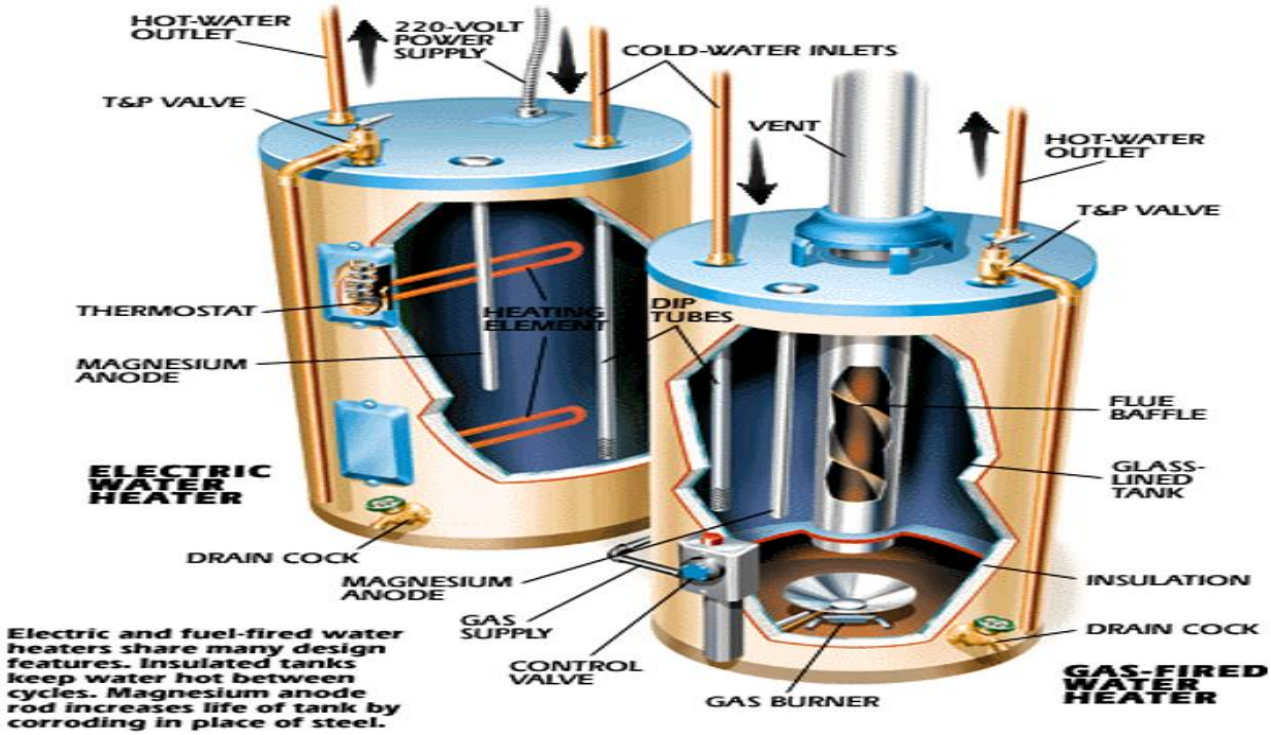

Figure 1. Conventional water heater.

Source: Klenck (1997).

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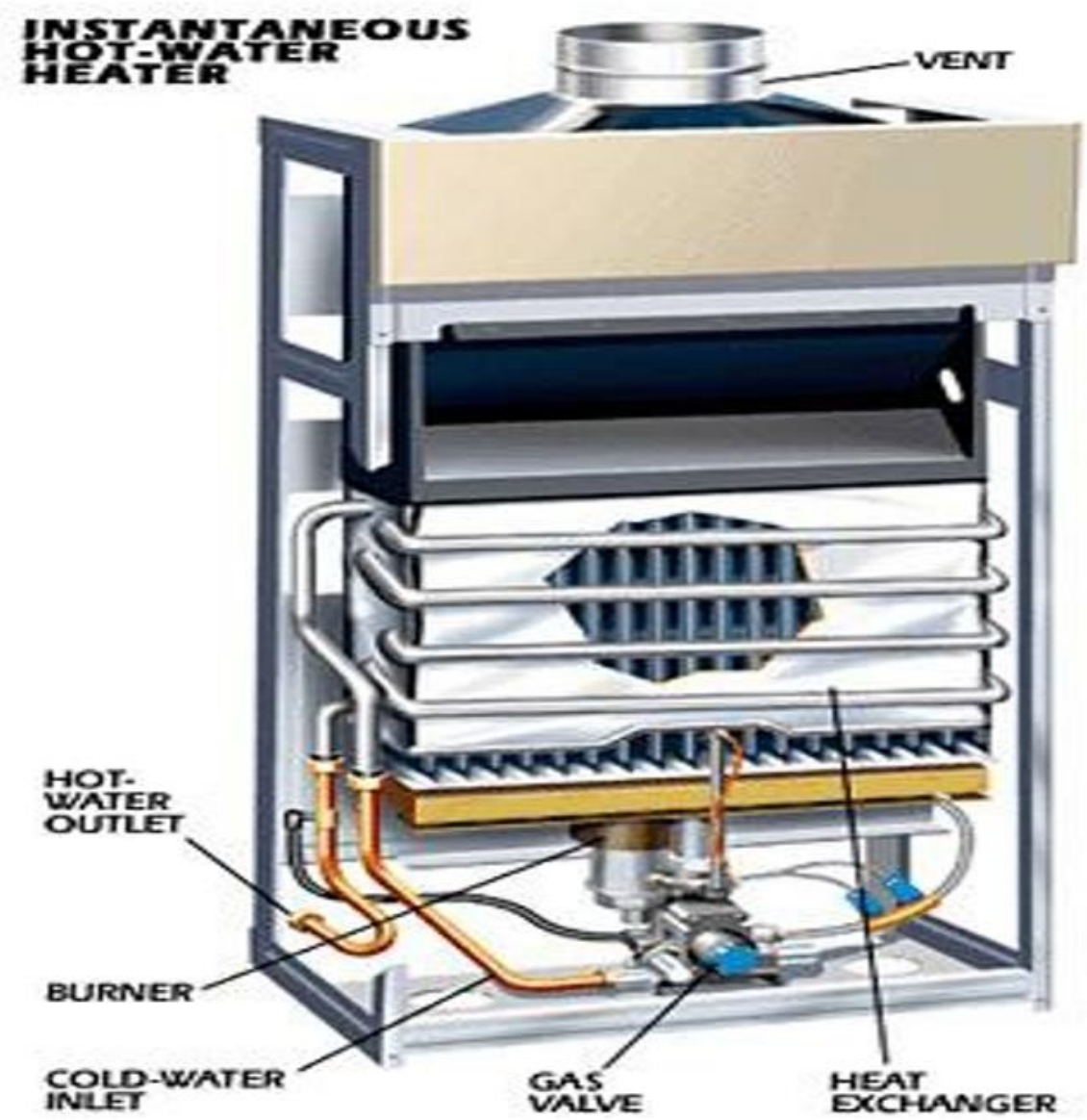

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Figure 2. Instant Water Heater.

(**Source:** Klenck (1997)).

The chance of tank failure or rupture can also be eliminated. Tank less water heaters required limited space and can be installed any where close to the point of use mostly indoors.

Tank less heaters do not store water, they are less subject to corrosion than conventional geysers. As a result, their expected equipment life is longer – more than 20 years, compared with 10 to 15 years for traditional heaters.

As they are not under pressure, tank less water heaters are less susceptible to leakage than tank- type water heaters. However, in areas with hard water, scaling can build up in the heat exchanger and reduce energy efficiency over time (Journal of Light Construction, 1997).

According to Gregor, Henze, P., and Coward (2009) there have been issues of temperature control with conventional methods controlling tank less water heaters, which typically allow a high degree of error in the outlet water temperature when subjected to disturbances in flow rate or inlet water temperature. The prime reason that many households today are shifting from the tank variety of hot water heaters to tank less variety are the huge cost savings. Tank less water heaters can save anything between 10% to over 40% even 60% in total hot water bills. The real saving is when uses the gas variations of tank less water heaters.

Gas based tank less water heaters including propane and kerosene, can heat much larger volumes of water to

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a higher temperature instantly. That is why tank less water heaters are recommended for the whole house units. Larger models will be able to handle even 3 to 4 simultaneous connections (Kevin, 2007).
Tank less systems are reliant on the water pressure which delivered to the property and can not be increased, whereas in tanked systems the tanks can be positioned above the water outlets so the force of gravity can assist in delivering the water and pumps can be added into system to increase pressure.
If tank less electric heaters are installed in a large percentage of homes within an area, may create demand management problems for utility providers. As they are high energy using devices and hot water use tends to peak at certain times of the day, their use can cause short spikes in electricity demand including peak load periods which increases operating costs.
Instantaneous type heaters are also problematic if they are connected to district heating systems as they raise peak demands and most utilities prefer all buildings to have hot water storage (Wikipedia, 2009).
US Department of Energy (2009) define that sedimentation may buildup in the tank. As water heaters age, they tend to accommodate sediment and lime deposits. If the heaters are not cleaned periodically, the sediment may rise to a level that will act as a barrier between the burner and the water, making it harder to heat and result in reduction of flow rate.

4. RESEARCH DESIGN

The research was carried out during the five months that is from December 2010 to April 2011 when the geysers are usually turned on. Since the research is considered as an exploratory study to compare the performance of conventional gas geysers and instant water heaters, therefore the most appropriate method of investigating the research was experimental research design. Based on the identification of five houses termed as an one experimental house and four control houses, research was conducted in the area of sector I-8, Islamabad with the selection of houses having approximately similar number of inhabitants (four or five family members) which supported to acquire the conducive results.
In the experimental house, where the conventional gas geyser and instant water heater had been installed and used on an alternate week basis, the amount of gas had been noted from the same meter to compare the performance of both. While in the control houses there were only the conventional geysers installed and readings were also noted on monthly basis during the same period to compare the consumption among all these control houses. The amount of excess water was also calculated in the experimental house on the basis of the distance of the faucets from the geysers along with the diameter and length of pipes that gave the amount of water stored in the pipes and had to be discharged prior to the availability of hot water in the faucets. The second part of the study was the use of questionnaire to get the perception and data about instant water heaters from different people along with their gas consumptions and amount of monthly bills they had received. There were 31 households from different sectors of Islamabad which were interviewed and the questionnaire was subsequently filled by them.
Data was collected from the experimental house by reading the gas meter every week for the experimental part of the research. The readings were recorded and amount of gas consumed during the week was noted along with the remarks about the type of geyser that was in use during the period. For the amount of water allowed to flow through the pipes before hot water was obtained the length of the pipes and diameter were noted with the pattern of the use of hot water and subsequently the amount of waste water in a day was calculated. The data was obtained and tabulate according to the necessary information required for research. The amount of savings that were obtained using the instant water geyser versus conventional one was calculated. The savings in the amount of the water utilized in accessing hot water were calculated.

5. DATA ANALYSIS

In the experimental house the conventional geyser and instant water heater had been used on an alternate week basis from December 2010 to April 2011. Even though there is on set of winters and increased gas utilization, the gas consumption by instant water heater is comparable less than the conventional one (Table 1). Therefore, in the experimental house the difference in gas consumption is significant and average weekly gas consumption is 17893 units while with the conventional one it is 36724 units (Figure 3). In the control houses, the gas consumption during five peak winter months when the heaters and geysers are being used had been observed. Average gas consumption in the control houses has been summarized in Table 2.
Therefore, it is evident that gas consumption in the experimental house which was using an instant water heater is the least of all the five houses (Figure 4). The use of instant water heaters does contribute to the savings in gas consumption and the amount of gas saved with respect to the control houses comes to 70%. However

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keeping in view the varying gas consumption requirements in each control house and the variation in the monthly use, we can study the pattern of the gas consumption in the experimental house, where the two geysers were used alternately on a weekly basis. The results of this show that the instant water geysers contribute savings of 50.7% (Table 3).

The amount of water wasted before hot water is obtained with conventional geyser was also calculated and tabulated in Table 4 and the amount of water wasted when instant water heater is used is shown in Table 5. These readings were calculated on the basis of distance of faucet from the geyser and the number of times the hot water was being used. The amount of waste water from instant water heater is 47% less than the conventional geyser. Thus, the results had shown an excess wastage of 6640 liters of water in just one household in the winter season of five months in order to get hot water in their faucets. Therefore, the data obtained and analyzed is evident that there is a considerable amount of saving of gas and water with the use of instant water heater with very limited drawbacks.

Table 1. Data on gas consumption n experimental house.

Types of geyser in use	Date		Gas units consumed weekly
	From	To	
Conventional Geyser	1-12-10	7-12-10	51861
Instant Geyser	8-12-10	14-12-10	31923
Conventional Geyser	15-12-10	28-12-10	45048
Instant Geyser	29-12-10	4-1-11	46676
Conventional Geyser	5-1-11	11-1-11	72666
Instant Geyser	12-1-11	18-1-11	55419
Conventional Geyser	19-1-11	25-1-11	59555
Instant Geyser	26-1-11	1-2-11	36506
Conventional Geyser	2-2-11	8-2-11	47340
Instant Geyser	9-2-11	15-2-11	36976
Conventional Geyser	16-2-11	22-2-11	47580
Instant Geyser	23-2-11	1-3-11	23291
Conventional Geyser	2-3-11	8-3-11	39886
Instant Geyser	9-3-11	15-3-11	16232
Conventional Geyser	16-3-11	22-3-11	35942
Instant Geyser	23-3-11	29-3-11	21763
Conventional Geyser	30-3-11	5-4-11	29486
Instant Geyser	6-4-11	12-4-11	16102
Conventional Geyser	13-4-11	19-4-11	29791
Instant Geyser	20-4-11	27-4-11	10237
Total			754280

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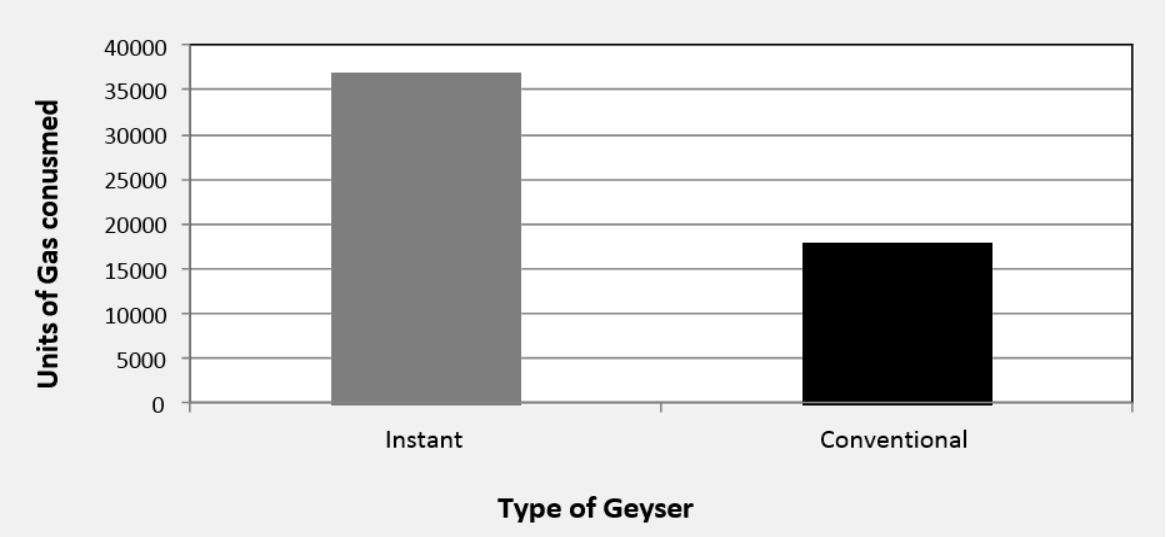

Figure 3. Comparison of weekly gas consumed using instant and conventional water geyser in experimental house.

Table 2. Average gas consumption in control house 1,2,3,4.

Remark	Gas consumed							
	Control House 1		Control House 2		Control House 3		Control House 4	
	Units	HM^3	Units	HM^3	Units	HM^3	Units	HM^3
Average gas consumed per month	126317	1.263	190400	1.904	144882	1.449	260569	2.606
Average per week	31579	0.316	47600	0.476	36221	0.362	65142	0.651
Gas consumed with geysers operational	1063800	10.638	1978200	19.782	2463000	24.630	3387400	33.874
Average per month with geysers	177300	1.773	282600	2.826	144882	1.449	260569	2.606

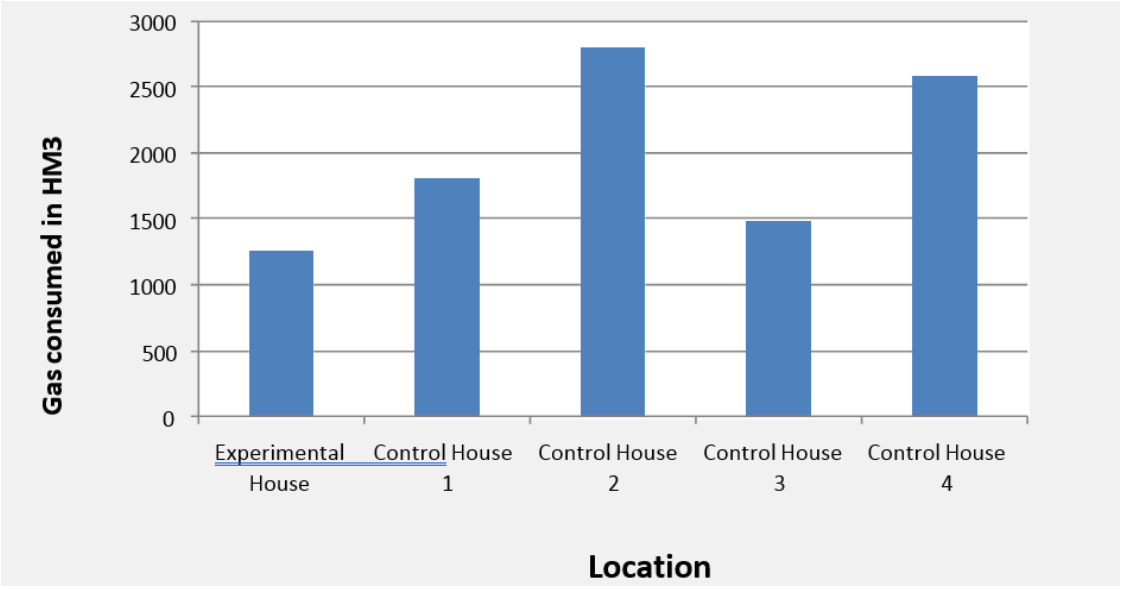

Figure 4. Average monthly gas consumption with geyser in use.

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Table 3. Gas savings in experimental house.

Winter months during Dec 10- Apr 11		
Gas consumed with instant water heater	284888	9 weeks
Average weekly gas consumed	31654	
Gas consumed with conventional water heater	429364	9 weeks
Gas consumed with instant water heater	47707	
Average saving per week with instant water heater	50.7	%

Table 4. Water wastage with conventional gas geyser.

Location of bath	No of times hot water used in a day	Distance of main line from conventional Geyser (m)	Diameter of main pipe (mm)	Length of branch pipe (m)	Diameter of branch pipe (mm)	Amount of water wasted before hot water was obtained (litres)
F	2	10.05	25	2.13	20	11.39
G	4	12.19	25	2.43	20	27.46
K	1	12.19	25	3.65	20	7.21
H	1	15.23	25	2.13	20	8.30
N, kitchen	3	12.19	25	13.10	20	29.73
Amount of water wasted in a day						84.17
Total liters of water wasted in a winter season (five months)						12625

Table 5. Water wastage with instant gas geyser.

Location of bath	No of times hot water used in a day	Distance of main line from Instant water Geyser (m)	Diameter of main pipe (mm)	Length of branch pipe (m)	Diameter of branch pipe (mm)	Amount of water wasted before hot water was obtained (litres)
F	2	3.65	25	2.13	20	4.90
G	4	2.13	25	2.43	20	7.08
K	1	3.65	25	2.43	20	2.54
H	1	1.52	25	2.13	20	1.36
N, kitchen	3	15.23	25	0.91	20	23.92
Total amount of water wasted in a day						39.90
Total litres of water wasted in a winter season (five months)						5985

6. FINDINGS

During the research comparison of gas readings show that for peak winter season from December to April the gas consumption in the experimental house was 7.142 HM^3 where as in control houses the average was 14.90 HM^3 and in the experimental house where the instant water geyser was used on an alternate basis, the energy consumption was less than any of the control houses. As far as saving of water is concerned, in the experimental house the water saving was 6640 liters in five months which is a big amount of treated water being allowed to flow in the sewer line before hot water is obtained in the faucets. In the experimental house the amount of water discharged from the pipes before the hot water was obtained was 18.54 gallons or 84.17 liters daily with conventional gas geyser. On the other hand by using instant water heater in the same house the water discharged to obtain hot water was 39.90 liters per day. Therefore, there is definitely a significant amount of savings in the requirement of energy needed for the water heating by use of instant water heaters.

From the questionnaire survey it was found that the knowledge on instant water heater is limited and even though 65% were only aware of the same but did not have sufficient information about it. 48% population did not have detailed information on the appliance. 11% felt the technology is too complicated and 15% did not have time to switch over to instant water heaters.

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7. CONCLUSIONS

Based on the study findings, it was found that Instant water heaters are more energy efficient and also conducive to water conservation:

- The amount of gas conservation in case of the experimental house and the control houses was 70 % during the winter months and the average over the whole year including summers the difference was a saving of 44 %

wherein the experimental house had the luxury of hot water through out the year.

- The instant water heaters also contribute towards conservation of water and the amount of water saved in the experimental house using instant water heater was about 6642 liters during the year, which amounts to 52.61%.
- Therefore, Instant water heaters, which have been in frequent use in the developed countries, have a definite edge in energy conservation for the supply of hot water to the users.

8. RECOMMENDATIONS

The study put forward the following recommendations:

- Government should take step to appreciate the people to install instant water heater in order to conserve the energy. Initially, the families that have installed instant water heaters may be given a 5-10% rebate in their bills; this will encourage the others to switch over to the instant water heaters. It is recommended that either the Government or SNGPL should introduce a tax credit for households using energy efficient appliances.
- The only reliable data on the instant water heaters was obtained from SNGPL, who had done work on the calibration of the gas consumption as well as the efficiency of the instant water heaters, but that was not available in printed form accessible to the public. It is recommended that they publish the same and make it available to all consumers, as is being done on sensitization of public on conservation methods on monthly gas bills.
- The Government has institutions dealing with energy conservation and there should be a service initiated wherein the consumers can obtain relevant information from these departments to get answers to their quarries.
- From the questionnaire it was seen that majority of the people did not have valid information on the instant water heaters and had not installed them in their homes due to lack of information and also the disbelief that instant water geysers would meet their hot water requirements without any compromise on the flow, yet with greater reduction in the gas consumed and the conservation of it. It is recommended that the use of instant water heaters should be encouraged and the Government and SNGPL should initiate a mass awareness program to sensitize the public.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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