AN EXPLORATORY STUDY OF POSSIBLE ENERGY SAVINGS AS A RESULT OF WATER CONSERVATION PRACTICES

Office of Water Resources Research and Technology Project
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CHAPTER I
INTRODUCTION

The evaluation of energy saved by using various alternatives of water conservation practices is studied in this report by the University of Oklahoma Bureau of Water and Environmental Resources Research for the U.S. Office of Water Resources and Technology (OWRT). The present work was originally considered as a pilot study to see what kinds of data were available, to what extent they might be utilized, and what general conclusions might be drawn from all these findings.

At the present time, there are quite a few studies done on the reduction of water and wastewater flow, reuse of household wastewater and cost analysis of water and wastewater treatment processes. However, there seemed to be an absence of comparative study on the relationship between savings of water and energy expenditures through the various water conservation practices. This study is an attempt to observe such relationship.

1.1 The Need

As this Nation has developed, its water use has increased substantially faster than its population. Since 1900, public water use has increased about 9 times. During this period the population increased about 2 times and water use per person increased about 3-1/2 times (25).

Alarmed by these facts, concerned people began to formulate, to experiment, and to rediscover the various ways and means of saving and conserving water. Through individual conservation practices within the home, two major ways have been approached as follows:

1) reducing flows through water supply outlets for various uses. Although the reductions in terms of monetary savings to each individual may be negligible, the reductions in the aggregate amount of water saved is readily noticeable. For example, a 20% decrease in the domestic home use of water through a redesigned toilet, in the aggregate, is essentially equivalent to discovering a 20% additional resource or the same as providing water supply for an additional 20% increase in population.

2) employing a reuse system to recycle a categorical domestic wastewater and then use it for another household usage, where potable water is not required, by means of minimal filtering or cleaning. The effect of this approach is also tremendous. For instance, if the 100 gpcd of domestic water were used through four places consuming 20 gpcd each time (100 to 80 to 60 to 40 to 20), the 100 gpcd now in reality becomes 300 gpcd.

In this age of energy crisis, however, the energy required for those conservation devices perhaps becomes more important than the supply of water. Energy consumed in pumping, heating, transmission, and operating for water production and wastewater treatment should all be considered. Perhaps, in this study, the most solicited answer is on: Will the additional energy required be of greater value than the savings in water?

1.2 Objectives and Purposes

The main concern of this study is to evaluate energy saved by using various alternatives of water conservation practices. The objectives are itemized as follows:

1) To determine the expenditures of energy involved in the application of water conservation practices in terms of the pumping, heating, and transmission in the reduction system as well as the operating in wastewater treatment and water production plants
2) To determine the total savings of water through the various conservation devices and/or systems
3) To convert the two results from 1) and 2) into commensurate units (eg. monetary values)
4) To determine the effectiveness level of the various devices and systems by application of cost-effectiveness analysis
5) To provide guidance for future related studies by listing of the various devices and systems in terms of overall savings

The purposes of this study are delineated as follows:

1) To provide information for the various water conservation alternatives as references for engineers, planners, manufacturers, water regulatory agencies and all water users
2) To provide actual quantitative information on water and energy saved by use of the various devices and a meaningful comparison of them according to their cost-effectiveness
3) To provide a set of standards for decision makers; To assist them in choosing the most appropriate devices or systems with dual consideration in resolving both the energy crisis and the existing excessive waste in water use
4) To provide a reminder for designer, planner and manufacturers, such that in the future consideration and decision making, the factor of energy consumption will be given better priority and weighting

1.3 The Approach

This study is developed entirely according to the primary objectives stated. Beginning with Chapter III: the current status of residential water use, observations are made on the patterns, quantities, categorization and fluctuations of conventional water usage. This is to be compared with the quantities of water consumed in various water conservation practices discussed in Chapter VI. - These are basic information required for calculating savings in water and energy.

Chapter IV briefly and quantitatively discusses the use of current energy resources as well as current and projected cost trends. This information is to be used as conversion basis for cost of energy expenditure in Chapter V and VII.

Chapter V summarizes the energy consumptions and costs in the conventional water supply and wastewater treatment plants, including the distribution and contributions of unit prices, consumptions and costs in sampled, typical and best plants. The calculated results are then directly used as the conversion factors for converting the amount of water saved to savings in energy from water supply and wastewater treatment processes through reduction of use. These conversion factors are thus used in the cost-effectiveness analysis in chapter VII.

A comprehensive survey of water conservation devices and hardware manufactures on available systems is conducted. All the possible techniques which can be applied in water conservation practices, as well as their advantage and disadvantage, are organized in terms of their specific use and shown in Chapter VI. They serve as the fundamental knowledge that is referred to when evaluating the cost-effectiveness of each alternative.

The work report in this study is directed toward a cost-effectiveness analysis of those devices and systems which are presented in Chapter VII.

CHAPTER II

CONCLUSIONS

In this research, the cost-effectiveness evaluation of the various water conservation practices, as stated previously, is merely an exploratory study of the possible savings in energy through the use of those alternatives mentioned. The fact that there are still many not considered made it clear that in concluding this analysis, one should not hastily and professedly recommend any particular device or system. Decisions should be based on priority and weighting. This study, which has oriented itself from an energy-saving perspective, thus accordingly rated the selected alternatives in terms of overall savings. (See Table 2-1 to 2-4). Naturally and logically, under this particular point of view, the higher the rating, the higher the effectiveness of the alternative.

In many phases of this research, numerous difficulties were encountered: some resolved, some recognized and some remained as a problem. Section 2.1 and 2.2 discussed the limitations recognized and recommendations for future studies.

2.1 Limitations

1) Limitation in identification of energy expenditure

In the cost-effectiveness analysis of this study, only four types

TABLE 2-1 OVERALL RATING FOR CATEGORIES OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS

Order of Rating		Category	Overall Saving # ($/home/yr)
1	B-b.**	Chemical toilet	+32.45
	B-c.	Freeze toilet	+32.45
	B-d.	Packing toilet	+32.45
	E-b.	Continuous aeration	+32.45
2	E-c.	Algae digester	+32.45
3	B-a.	Bucket	+31.51
	A-a.	Pit latrine	+30.42
	A-b.	Aqua privy	+30.42
	B-e.	Recirculating chemical toilet	+30.42
4	C-a.	Vacuum truck	+30.33
5	C-b.	Chemical privy	+29.75
6	C-d.	Water-borne network	+18.93
7	E-a.	Compost privy	+10.55*
8	C-c.	Recirculating fluid toilet	+10.15
9	C-e.	Vacuum network	+8.66*
10	F.	Household waste treatment plant	+4.47*
11	D-a.	Incinerating toilet	-40.55*

#These are based on the median figure of savings of the various devices in each category

*These figures are also shown in Table 7-5

**Refer to Table 7-1

TABLE 2-2 OVERALL RATING FOR CATEGORIES OF WATER CONSERVATION SHOWERHEAD, VALVE AND FAUCET INSERT DEVICES

Order of rating	Category	Overall saving ($/home/yr)
1	A.* Limiting flow valves for shower	+11.93
2	B. Thermostatic mixing valve in tub and shower	+ 3.97
3	C. Limiting flow valves for lavatory	+ 1.00
	D. Limiting flow valves for kitchen sink	+ 1.00
	E. Aerator faucet for lavatory and kitchen sink	+ 1.00

*Refer to Table 7-2

TABLE 2-3 OVERALL RATING FOR CATEGORIES OF WATER RECYCLE SYSTEMS

Order of rating	Category	Overall saving # ($/home/yr)
1	B.** Reuse of wash water for toilet flushing only	+10.54*
2	A. Reuse of wash water for toilet flushing and lawn sprinkling	+8.68*
3	D. Reuse of non-sanitary wastes for toilet flushing after filtration, and for laundry after distillation	-20.48*
4	C. Distillation of wastes with reuse for all but drinking & cooking	-107.64*

#These are based on the median figure of savings of the various devices in each category

*These figures are also shown in Table 7-6

**Refer to Table 7-3

TABLE 2-4 OVERALL RATING FOR CATEGORIES OF OTHER WATER CONSERVATION APPLIANCES

Order of rating	Category	Overall saving ($/home/yr)
1	B.* Front loader washer	+8.10
2	A. Automatic clothes washer	+2.21

*Refer to Table 7-4

of immediate savings in energy from water saved is numerically used in estimation (See Sec. 7.1) and not all indirect or pertinent energy expenditures are included. Table 7-1 to 7-4 only contain the savings of energy identified by the researcher, but it is the belief of the researcher that all major items are encompassed and the results obtained should be highly reliable.

2) Data information does not fall in the same time framework

The cost-effectiveness analysis of this study is aimed at all the newly developed conservation devices and systems, and thus, all cost assumptions used should also be the latest ones. Unit water cost and energy cost are updated normally, but figures used on unit consumptions in water supply and wastewater treatment plant and heating cost of hot water were reconciled to those from the past several years. However, observation of figures on Table 7-1 to 7-4 indicated that the proportional weights of the later figures were relatively small and were of merely minor influence to the determination of its effectiveness.

3) Different assumptions were demanded by each particular alternative

The different types of devices and systems collected in Chapter VI came from different corners of the world, each has its own unique development background characteristics. Thus, many of them were calculated with assumptions as stated in Appendix B. Assumptions were made as if these units were built in the U.S., and estimation of the various expenditures were based on U.S. standards.

4) Comparison among the various devices or systems is not possible because the difference in purposes

Unlike the cost analysis performed by previous researchers, where all possible candidates can be cost-effective analyzed as a group, this study separated all the candidates into four groups prior to the cost analysis. The four groups are namely: toilet insert devices and systems, showerhead, valve or faucet insert devices, water recycle systems and other appliances. This is because of the vast differences among the candidates. To compare devices or systems of such magnitude of differences in purpose and use is needless to say meaningless.

2.2 Recommendations

In the course of collecting and analyzing the data, many difficulties remained unsolved even up to the final stage of the research. A few, in particular, seemed to have more urgent need of future studies:

1) Collecting and recording of data on energy expenditures of every water supply and wastewater related processes need to be more independent and systematic.

The shortage of energy resources is already a known fact. A more independent and systematic procedure is required for collecting, updating and recording data on energy consumption of water and wastewater treatment, construction, transmission and distribution,etc. This is an absolute need required by future studies.

2) Continual collection and analysis of data on water conservation alternatives must be done cooperatively and systematically.

Many "appliances" are believed to be in the process of being developed. If information on these can be collected as the report

"Stop the five-gallon flush" (19), it will be of great value to future cost-effectiveness analysis.

3) Future researchers should try to proceed in the same direction, but beyond this study in applying more diversified energy terms to compare savings in water and energy.

This is to base on the first recommendation and to identify all possible indirect energy processes, and then observe whether the cost-effectiveness rating will be affected or not.

4) The rating of overall saving (as performed in this report) could be compared with rating from total cost analysis.

This can be done by adding the items of conventional cost-effectiveness analysis into considerations. These items are, for instance, amortized capital cost, annual maintenance cost, treatment cost, labor cost, etc.

Then observe this rating to see if there is any difference in the order of effectiveness.

CHAPTER III

CURRENT STATUS OF RESIDENTIAL WATER USE

3.1 Patterns of Residential Water Use

Present water use patterns have been divided into four categories: residential, commercial, industrial, public, and the water which is not accounted for. To describe residential water use, demands are usually separated into domestic and lawn sprinkling use. Domestic water use includes drinking, cooking, bathing, washing, and carrying away of wastes. Nearly all domestic water is discharged into sewers and goes back to a natural body of water. Thus, domestic use is nonconsumptive. Sprinkling use is water applied to lawns when precipitation fails to meet requirements. Since most of this water is returned to the atmosphere by evapotranspiration, sprinkling use is consumptive. Fig. 3-1 shows the schematic diagram of residential water use. The detailed classification of domestic water usage and their percentage use are presented in Fig. 3-2.

3.2 Quantity of Residential Water Use

Many factors influence residential water use for a given system. For example, the mere fact that water under pressure is available stimulates its use for watering lawns and gardens, for washing automobiles, for operating air-conditioning equipment, and for performing many other utility activities at home and on the farm. Modern kitchen and laundry appliances, such as

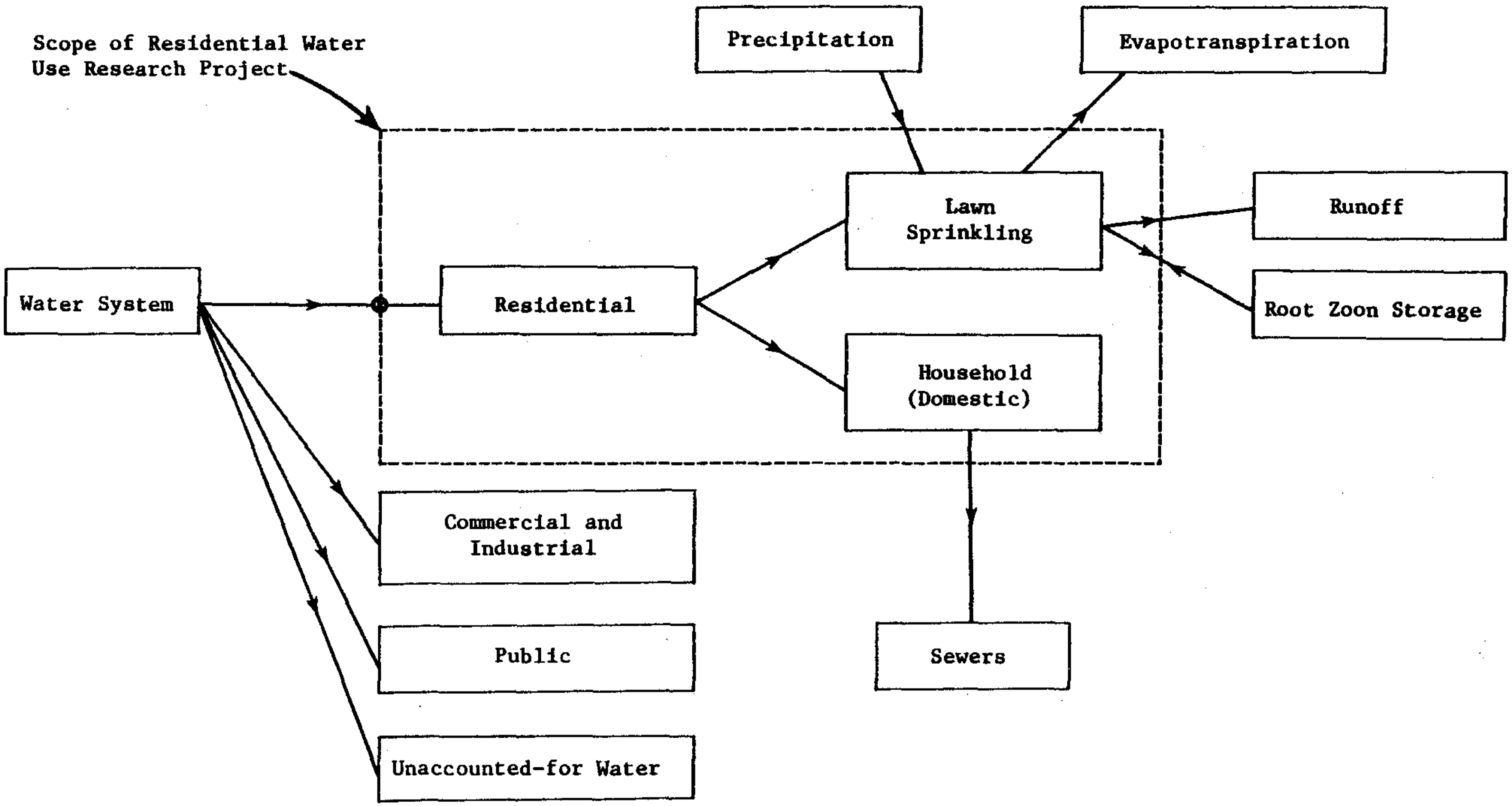

Fig. 3-1 Schematic Diagram of Residential Water Use

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*Source: Linaweaver Jr., F. P., et al., Summary Report on the Residential Water Use Research Project, Journal of AWWA, 59, 3, 1967

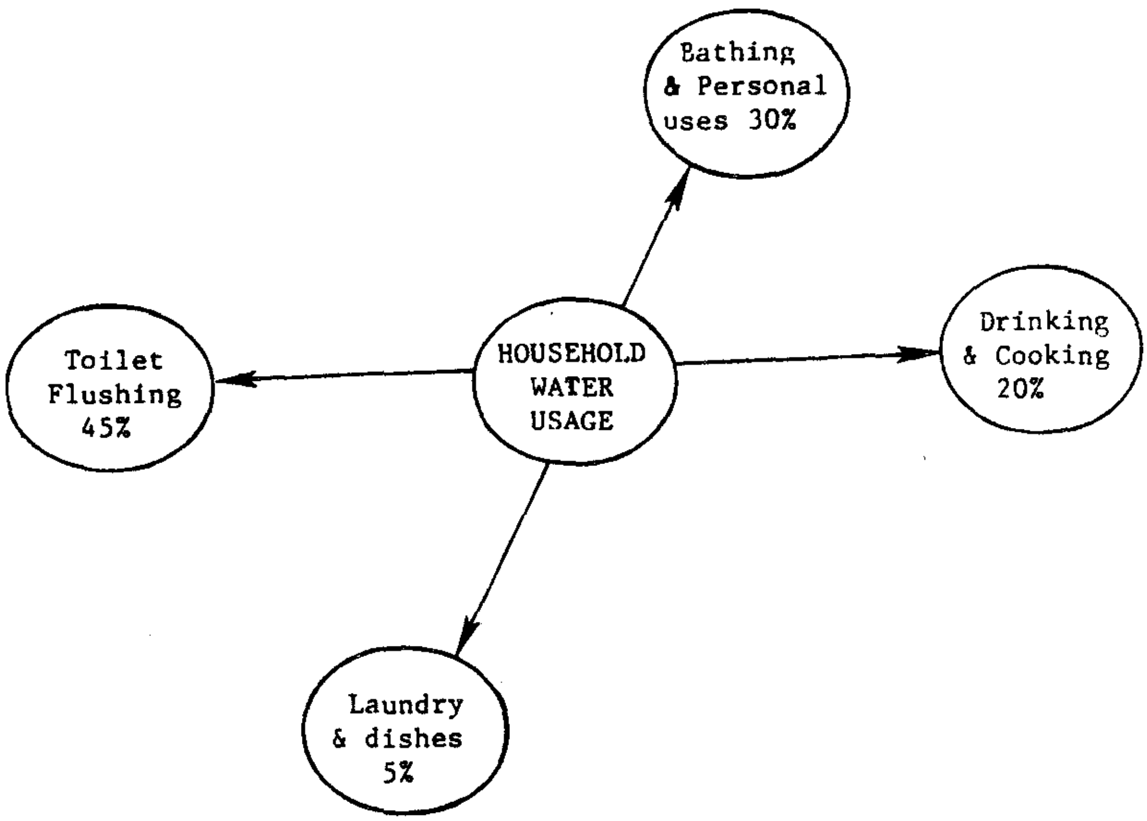

Fig. 3-2 Classification and Percentage of Household Water Usage

Source: Howe, et al. Future Water Demands: 1970-1990. A study for the National Water Commission by Resources for the Future, Inc., June, 1970 food waste disposers and automatic dishwashers, contribute to a higher total water use and tend to increase peak demands.

There has been a great number of reports which show that per capita water use varies widely with the standard of living, the climate, personal habits, and the number of persons per dwelling unit (2). The actual amount of water (not including lawn sprinkling) varies from less than 20 to more than 100 gpcd (gallons per capita per day). The figures most widely reported are between 40 and 80 gpcd. Public Health Service revealed that the average daily water use was 56 gallons per person. A study at Johns Hopkins University also indicated an average per person use of 56 gpd. Both of these studies indicated that gpcd water use was inversely proportional to the number of persons per dwelling unit. In addition, the Public Health Service found that the statistical average water use (not including lawn sprinkling) fit the formula:

$$Q = 88 + 26 P$$

where

Q = The daily gallons of water used per household

P = The number of persons per household

Table 3-1 presents a summary of average water use estimated by E.P.A. Among the fifty-seven types of establishments, seven residential uses were labeled with stars. From these figures, an average of 55 gpcd is estimated for the residential uses.

Residential water usage accounts for a very small proportion of actual total water consumed in this country. Based on the projection from the first National Assessment of the Water Resources Council, the estimated residential water demand of 4,850 million gallons per day in 1980 is less than 1.1 percent of the total demand of 442,630 million gallons daily for all purposes. (See

TABLE 3-1: SUMMARY OF AVERAGE WATER USES

	Types of establishments	Gallons per day	
	Airports (per passenger)	3-5	
*	Apartments, multiple family (per resident)	60	*
	Bath houses (per bather)	10	
	Camps:		
	Construction, semipermanent (per worker)	50	
	Day with no meals served (per camper)	15	
	Luxury (per camper)	100-150	
	Resorts, day and night, with limited plumbing (per camper)	50	
	Tourist with central bath and toilet facilities (per person)	35	
	Cottages with seasonal occupancy (per resident)	50	
	Courts, tourist with individual bath units (per person)	50	
	Clubs:		
	Country (per resident member)	100	
	Country (per nonresident member present)	25	
	Dwellings:		
*	Boardinghouses (per boarder)	50	*
*	Additional kitchen requirements for nonresident boarders	10	*
*	Luxury (per person)	100-150	*
*	Multiple-family apartments (per resident)	40	*
*	Rooming houses (per resident)	60	*
*	Single family (per resident)	50-75	*
	Estates (per resident)	100-150	
	Factories (gallons per person per shift)	15-35	
	Highway rest area (per person)	5	
	Hotels with private baths (2 persons per room)	60	
	Hotels without private baths (per person)	50	
	Institutions other than hospitals (per person)	75-125	
	Hospitals (per bed)	250-400	
	Laundries, self-serviced (gallons per washing, i.e., per customer)	50	
	Livestock (per animal):		
	Cattle (drinking)	12	
	Dairy (drinking and servicing)	35	
	Goat (drinking)	2	
	Hog (drinking)	4	
	Horse (drinking)	12	
	Mule (drinking)	12	
	Sheep (drinking)	2	
	Steer (drinking)	12	
	Motels with bath, toilet, and kitchen facilities (per bed space)	50	
	With bed and toilet (per bed space)	40	
	Parks:		
	Overnight with flush toilets (per camper)	25	
	Trailers with individual bath units, no sewer connection (per trailer)	25	
	Trailers with individual baths, connected to sewer (per person)	50	
	Picnic:		
	With bathhouses, showers, and flush toilets (per picnicker)	20	
	With toilet facilities only (gallons per picnicker)	10	
	Poultry:		
	Chickens (per 100)	5-10	
	Turkeys (per 100)	10-18	
	Restaurants with toilet facilities (per patron)	7-10	
	Without toilet facilities (per patron)	2½-3	
	With bars and cocktail lounge (additional quantity per patron)	2	
	Schools:		
	Boarding (per pupil)	75-100	
	Day with cafeteria, gymnasiums, and showers (per pupil)	25	
	Day with cafeteria but no gymnasiums or showers (per pupil)	20	
	Day without cafeteria, gymnasiums, or showers (per pupil)	15	
	Service stations (per vehicle)	10	
	Stores (per toilet room)	400	
	Swimming pools (per swimmer)	10	
	Theaters:		
	Drive-in (per care space)	5	
	Movie (per auditorium seat)	5	
	Workers:		
	Construction (per person per shift)	50	
	Day (school or offices per person per shift)	15	

*Residential Water Uses

Source: E.P.A. Water Supply Division, Manual of Individual Water Supply Systems,1974

Table 3-2).

3.3 Categorical Usage of Water in the Home

The water delivered to the household is divided among the various uses in a different manner in every household. A typical estimate of water used in the home of an average family of the future consisting of four members is shown in Table 3-3. The average daily use was estimated as 86.5 gpcd with lawn sprinkling of 90 days a year and two hours per watering. The figures shown in the table do not correspond to the exact use patterns of every family, but its purpose is merely to emphasize significant water use trends. For example, 71.5 percent of the total household water intake is used in bathing and toilet flushing. These functions use a greater amount of water than other household activities and therefore should afford the greatest savings in water use (16).

A model home with an average family which uses and disposes of water in the average way was fabricated in a study conducted by General Dyamics (2). This average home is a three bedroom structure with 1-1/2 bathrooms, having a shower and tub or a shower - tub combination, and a basement or storage room. The home also has an automatic washing machine and probably a dishwasher and garbage disposal unit. The occupants in this home consist of two adults and two children. A chart of water used in the daily operation of this model family was constructed from the results of many different water use studies as published in various sources (including Table 3-3). This chart of average household water requirements is shown in Figure 3-3.

3.4 Residential Water Use Fluctuations

The rate of water use for a residential water system will vary directly

TABLE 3-2: ESTIMATED WATER USE: 1940 TO 1974, AND PROJECTIONS TO 1980
(in Billion Gallons per Day)

Year	Total Water Use	Irrigation	Public Water Utilities	SELF-SUPPLIED USES		
				Rural domestic	Industrial and miscellaneous	Steam electric utilities
1940	136.43	71.03	10.10	3.10	29.00	23.20
1950	202.70	100.00	14.10	4.60	38.10	45.90
1960	322.90	135.00	22.00	6.00	61.20	98.70
1965	269.62	110.85	23.74	4.08	46.41	84.54
1970	327.30	119.18	27.03	4.34	55.95	120.80
1973	361.89	124.18	29.00	4.49	61.67	142.55
1974	373.41	125.84	29.65	4.54	63.58	149.80
1980	442.63	135.85	33.60	4.85	75.03	193.30

a. Total take, including delivery loses , but not including reservoir evaporation.
b. Rural farm and nonfarm household and garden use, and water for farm stock and dairies.
c. For 1940-1960, includes manufacturing and mineral industries, rural commercial industries, air-conditioning, resorts, hotels, motels, military and other State and Federal agencies, and other miscellaneous uses; thereafter, includes manufacturing, mining and mineral processing, ordinance, and construction.

*Source: Statistical Abstract of the United States, 1975

TABLE 3-3 ESTIMATED RESIDENTIAL WATER USE OF AN AVERAGE FAMILY OF THE FUTURE*
(including lawn sprinkling)

Water-use Item	Daily Family Use (gpd)	Daily Per Capita Use (gpcd)	Percentage Use (excluding lawn watering)
Lawn Watering	100	25.0	
Toilet	96	24.0	39.0
Bathing	80	20.0	32.5
Laundering	34	8.5	13.8
Dishwasher	15	3.75	6.1
Autowashing	10	2.5	4.1
Drinking and Kitchen	8	2.0	3.3
Garbage Disposal Unit	3	0.75	1.2
TOTAL	346	86.5	-
All Uses Except Lawn	246	61.5	100.00

* A family consists of four members in a house with two bathrooms, a garbage disposal, a dishwasher and an automatic washer.

Source: Reid, G. W., "Projection of Future Municipal Water Requirements", Southwest Water Works S. 46:18, 1965

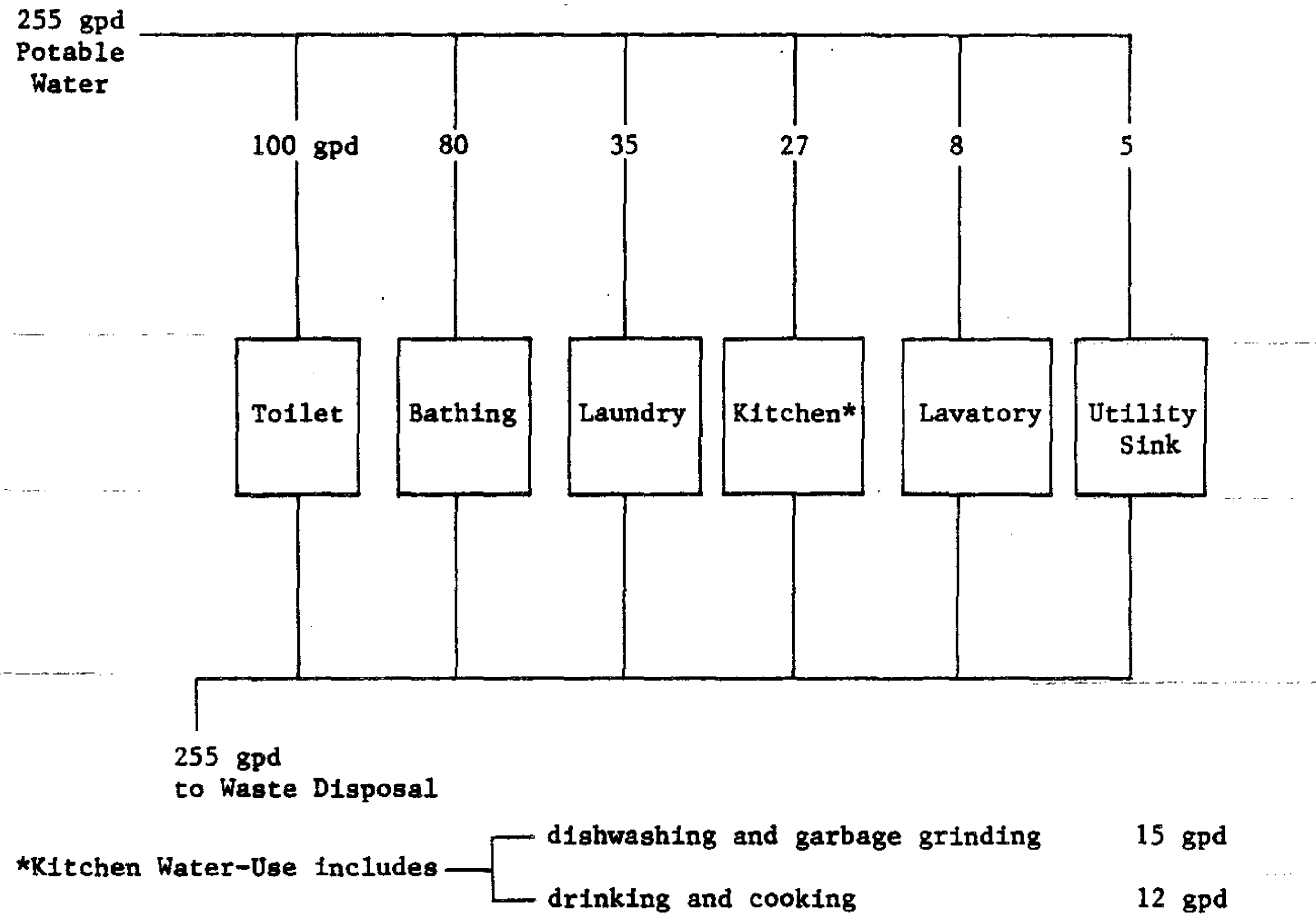

Fig. 3-3: Average Household Water Requirements*

Source: Bailey, J. R., et al. A study of Flow Reduction and Treatment of Waste Water from Households. Federal Water Quality Administration, Cincinnati, Ohio. December 1969.

with domestic activity in the home. Rates are generally highest in the home near mealtimes, during midmorning laundry period, and shortly before bedtime. During the intervening daytime hours and at night, water use may be virtually nil. Thus, the total amount of water used by a household may be distributed over only a few hours of the day, during which the actual use is much greater than the average rate.

Simultaneous operation of several plumbing fixtures will determine the maximum peak rate of water delivery for the residential water system. For example, a shower, an automatic dishwasher, a lawn-sprinkler system, and a flush valve toilet all operated at the same time would probably produce a near-critical peak. It is true that not all of these facilities are usually operated together; but if they exist on the same system, there is always a possibility that a critical combination may result, and for design purposes, this method of calculation is sound.

Hourly fluctuations are due to levels of human activity found within the family. A low period occurs between 12 a.m. and 6 a.m., when most people are sleeping, water usage drops to near zero on a dwelling unit basis, then picks up sharply and peaks about 7-8 a.m. Water usage does not vary much throughout the day but remains elevated over nighttime levels due to cooking, cleaning, and washing which take place in the home. A peak after 6 p.m. is attributable to family members again active around the house, i.e. washing dishes, flushing toilets and bathing.

Figure 3-4 shows a weekly pattern of hourly water use during winter and summer. The solid curve on the graph is for summer use; broken curve for winter. As we can see, hourly variation in use is widely divergent. The great difference between winter and summer hourly peaks is resulted from the fact that winter use is for domestic or household purposes while summer excess is

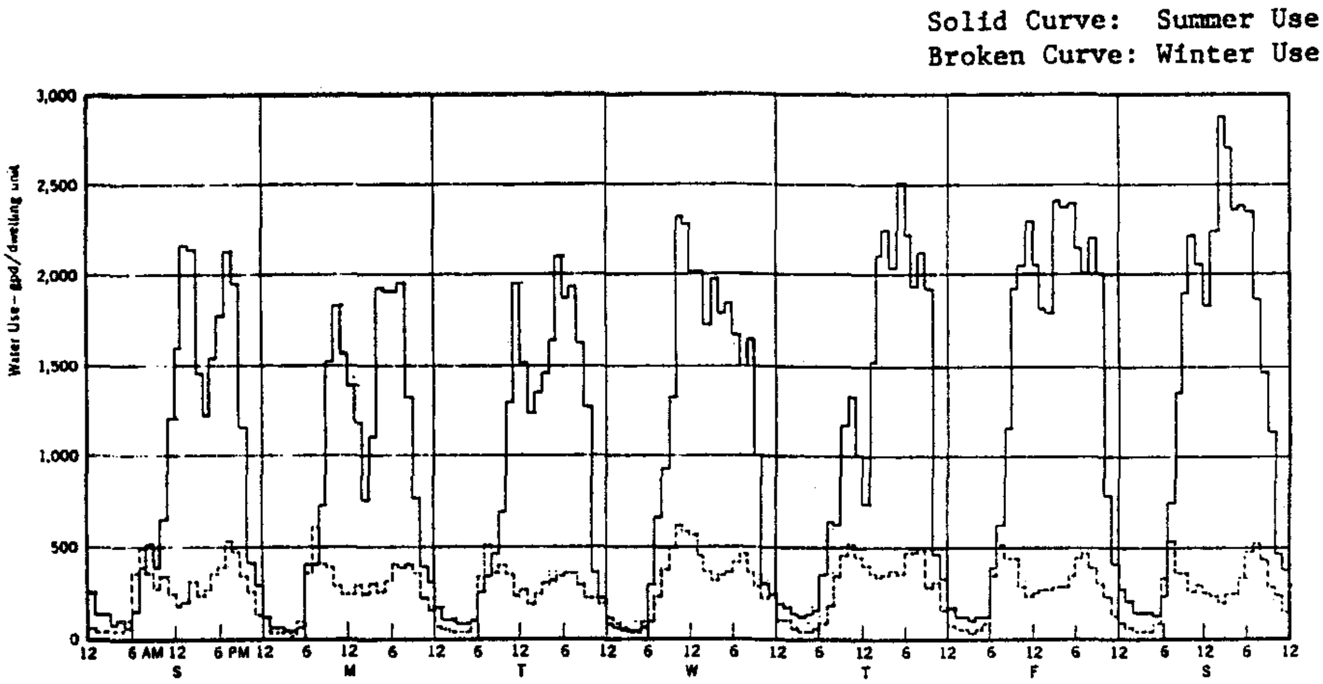

Fig. 3-4: Weekly Pattern of Hourly Water Use During Winter and Summer*

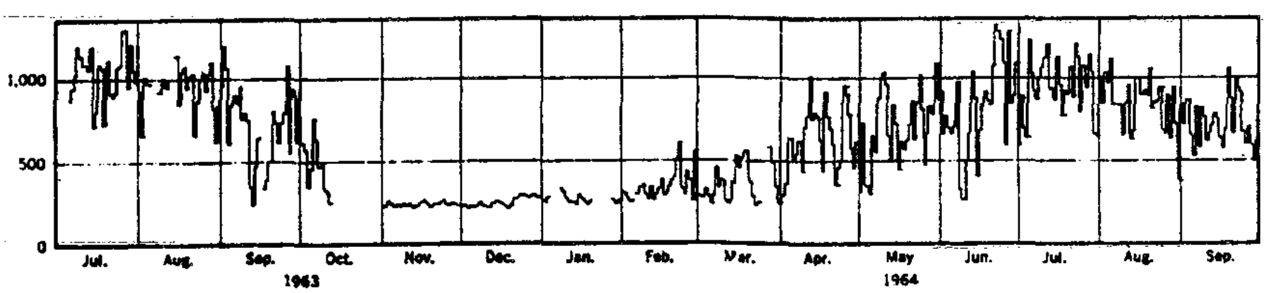

Fig. 3-5: Seasonal Pattern of Daily Water Use*

*Source: Linaweaver, F.P., et.al. Residential Water Use Research Project, Journal AWWA, 59: 270, Mar., 1967 for lawn irrigation.

Seasonal variations, on the other hand vary drastically, especially in the western U.S.(12). Fig. 3-5 shows a typical seasonal pattern of daily water use in California. During winter months daily water use varies little; as the growing season approaches, water use increases and reaches a peak during the summer. This phenomenon is due largely to lawn and garden sprinklings while levels of sprinkling are dependent most on local climatology. An excess of potential for evapotranspiration over precipitation levels will cause many residential consumers to sprinkle their lawn or gardens. The largest volumes of water sprinkling generally occur on the hottest days, after prolonged periods without precipitation. Rainfall during these periods of heavy sprinkling demand will greatly reduce the usage of water for home irrigation. Utilities serving large populations that live in apartments will not have as high a demand for water as one serving a disproportional share of single family dwellings with cultivated greenery in the yard.

3.5 The Necessity of Residential Water Conservation

It has been a generally accepted premise in this country that water use per capita will continue to rise and that growing demand for water services will be met through the development of new supplies. This attitude has prevailed generally in the United States but no where has it been more evident than in west.

These additions to supply have been considered essential to economic growth, and the continued use of large quantities of water for irrigation has been widely viewed as a necessity if the Western economy is to prosper. In recent years it has become increasingly difficult to fulfill these premises. The Southwest has been confronted with rapidly declining ground water supplies and the Northeast was forced to ration water during the recent drought (4).

The difficulty of developing additional water supplies has been accompanied by changes in technology and advances in our understanding of national and regional economies which has led to a questioning of the traditional premises. Now it is being suggested that demand can be manipulated as well as supply.

In 1967, the average or typical household in the United States spent between $57 and $87 each year on water and sewage systems depending on the service provided (5). An estimate of $90 per year of water and waste costs for a family of four was made by Bailey and Wallman in 1971 (3). These figures are probably closer to 100 dollars now, due generally to inflation. In areas without public sewage systems, the average revenue charge for metered water in 1967 was 68 cents per 1,000 gallons. At this price there seems little to encourage the public to conserve water.

Various "flow reduction" devices are available, however, which will pay for themselves over a number of years by reducing water costs (See Chapter VI). Also available are flush toilets which use only three to four gallons of water per flush as compared with the usual five gallons. "Dual flush" toilets which only use one gallon of water when urine is to be disposed of, can provide an overall savings of around 2-1/2 gallons. Spray faucets can be as effective as conventional ones and only use half as much water, and pressurized "automizers" could theoretically provide a whole shower-bath with only one pint of water. The purchase cost and yearly savings for a number of water-saving devices currently available is shown in Table 3-4.

Recycling the household water supply requires the installation and maintenance of some kind of filtration system. It has already been estimated that even the reuse of bath water for toilet flushing would ultimately cost

TABLE 3-4: ESTIMATED INSTALLATION COSTS AND YEARLY SAVINGS OF VARIOUS FLOW REDUCTION DEVICES*
(for a family of four)

Flow Reduction Devices	Purchase and Installation Cost	Yearly Savings For Family of Four
1. Flow Control Shower	$ 50.00	$12.00
2. Reduced Flush Toilet	110.00	15.00
3. Dual Flush Toilet	30.00	20.00
4. Vacuum Flush Toilet (on basis of 100 homes)	295.00	31.00
5. Washing Machine (extra cost for level controls)	35.00	2.00

*Source: 5

more than the corresponding saving due to reduced water consumption. However, on a larger scale the treatment of water for reuse in the household becomes more feasible. The system of recycling (washing water in a cluster of 32 houses), would provide an overall savings of around $4.70 per day (at 70 cents per 1000 gallons), which, over a period of 20 years would amount to over 35,000 dollars. It is difficult to estimate how much of this saving would be offset by maintenance and operation costs, but it seems reasonable to assume that a filtration system would pay for itself. Given a situation where the only alternative is a large septic field, the benefits of an above ground recycling system would be considerable.

CHAPTER IV

CURRENT STATUS OF ENERGY RESOURCES IN U.S.

4.1 Current Energy Supplies and Consumptions

The U.S. Geological Survey estimated that the energy resources* inventory in the United States totals 50 quintillion BTU's (or 50 x 10^{18} BTU's). The constituents of the available energy resources are coal, uranium, oil, natural gas, etc. Percentages of these constituents are shown in Fig. 4-1.

The total production of energy resources in the United States in 1974 has been estimated by the Bureau of Mines as 60,564 trillion BTU, but the total energy consumption for 1974 was 73,121 trillion BTU, indicating a deficit of 20.7%.

As the graph shown in Fig. 4-2, energy resource supplies and the current rate of resource consumption is completely out of balance.

Dividing the proven energy reserves by the current rate of consumption will produce the results shown in Table 4-1. Obviously, we cannot continue the present pattern of energy consumption.

4.2 Quantity of Residential Energy Consumption

According to the annual report of Federal Power Commission, residential

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*Energy Resources are defined as: Discovered and yet undiscovered deposits likely to be found, including submarginal deposits which would require new technology and higher prices for recovery.

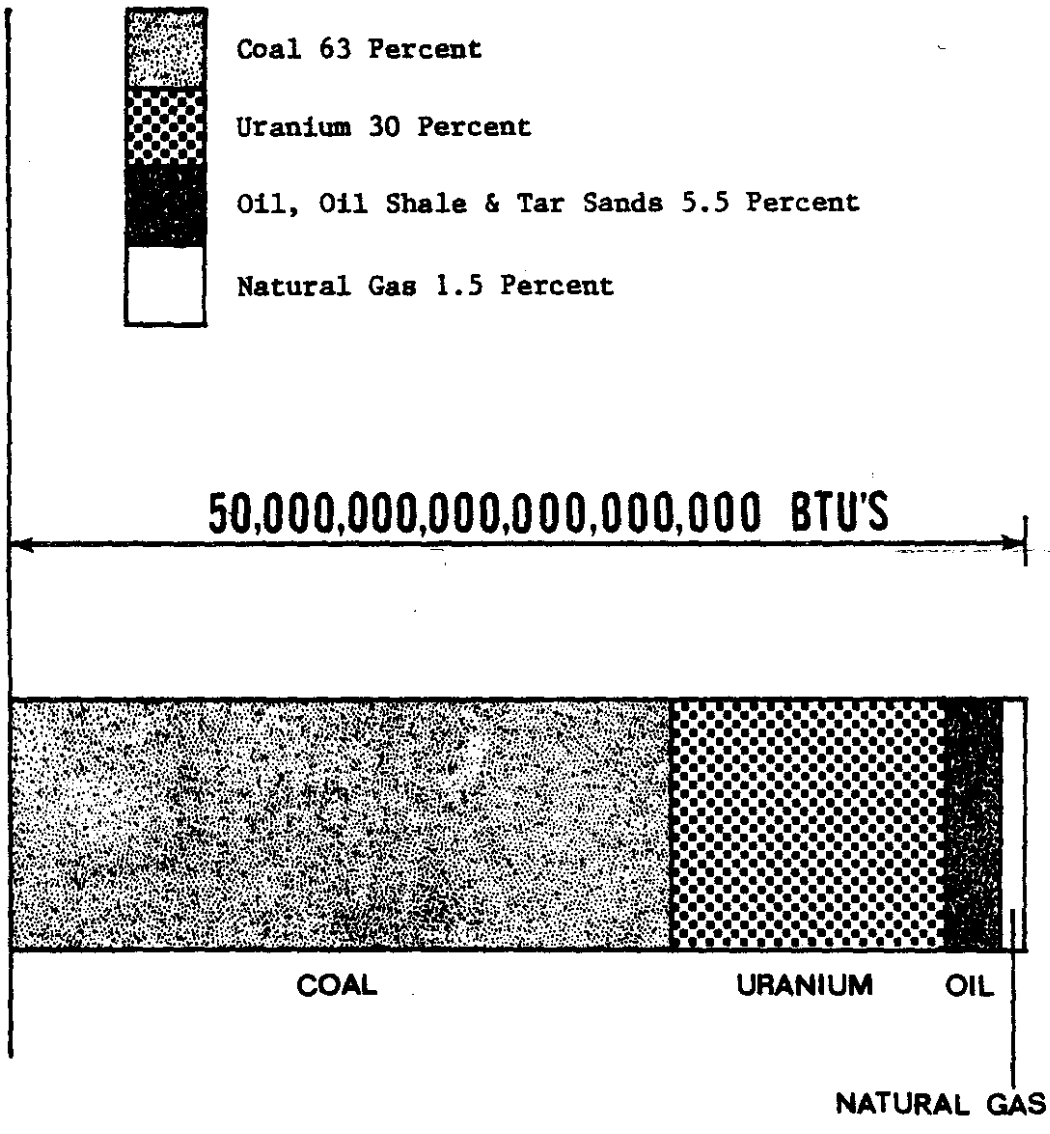

Fig. 4-1 Percentage of Constituents in U.S. Energy Resources*

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*Source: U.S. Geological Survey

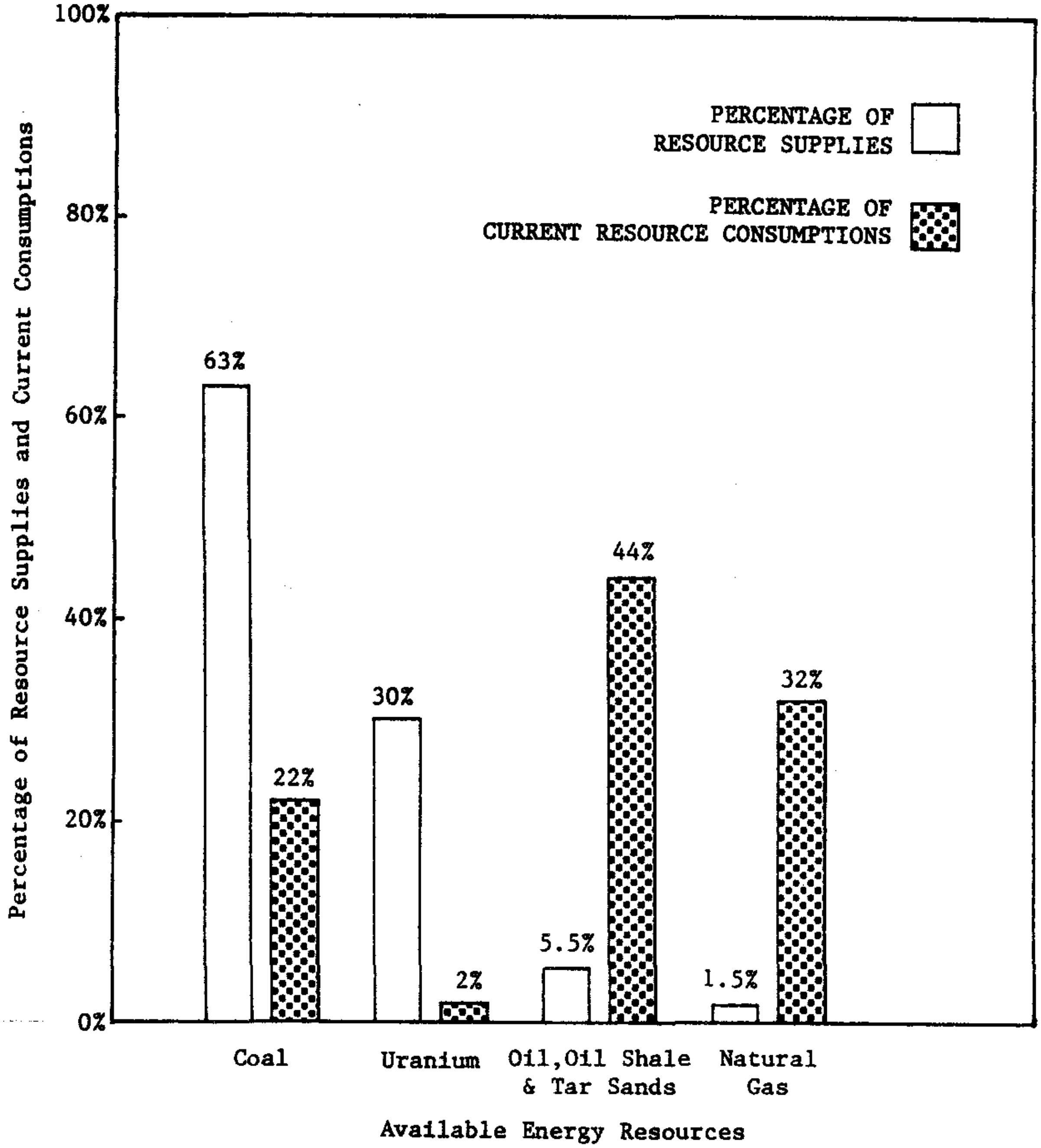

Fig. 4-2 Total U.S. Energy Resources Compared to Current Resource Consumptions*

*Source: U.S. Geological Survey

TABLE 4-1 TIME TO DEPLETION OF U.S. ENERGY RESOURCES AT PRESENT RATE OF CONSUMPTION*

ENERGY RESOURCE	SUPPLY IN YEARS
Oil	10
Natural Gas	13
Coal	650
Uranium	1,250

*Source: O.G.&E., "The Dawn of a New Energy Era with Electricity" sales of electrical power totaled 554,960 million KWH in 1974, which represented about 29.8% of the total power generated. (see Table 4-2). But the average consumption of electrical power varied significantly with the area of the area of the country from a high of 19,636 KWH/yr/household in Eugen, Oregon to a low of 2,275 KWH/yr/household in Bronx, New York.(22)

As shown in Table 4-2, residential electricity uses in 1975 showed a 6.5% increase (36.1 billion KWH) over 1974, to 591 billion KWH. This is up dramatically from 1974, when residential uses increased to a mere 0.14% over 1973. This category still represents about a third or 34% total KWH uses.

Average annual use per residential customer in 1975 showed a gain of 339 KWH to 8,246 KWH. This was up 4.3% over 1974, when average KWH use per customer dropped for the first time in more than a generation by 2.1% to 7,907 KWH.

4.3 Energy Cost for Residential Use

4.3.1 Past Status

An annual survey of 1976 conducted by the Electrical World Magazine reported that fuel cost continued to exert a significant effect on electricity rates even though this pressure moderated somewhat in 1975. In 1974, rapidly rising fuel costs, passed on to customers through the fuel-adjustment charge accounted for about two-thirds of the increase in the cost per KWH. Since these costs "stabilized" around the end of 1974, higher fuel charges in 1975 account for about 46% of the increase in the cost per KWH. (1)

TABLE 4-2 ELECTRIC ENERGY GENERATED, SALES AND CUSTOMERS*: 1950-1975

CLASS \ YEAR	1950	1955	1960	1965	1970	1971	1972	1973	1974	1975#
Energy Generated...bil.KWH	329	547	753	1,055	1,532	1,614	1,747	1,856	1,865	N.A.
Sales to Ultimate Customers (Total Sales)...bil.KWH	281	481	683	953	1,391	1,466	1,578	1,703	1,701	1,736
or Domestic...bil.Kwh	70	125	196	281	448	479	511	554	555	591
Ratio of Residential to Total	25.0%	26.1%	28.7%	29.5%	32.2%	32.7%	32.4%	32.5%	32.6%	34.0%
Ultimate Customers,(Total, Dec. 31)...millions	45.0	52.6	58.9	65.6	72.5	74.3	76.2	78.5	80.1	81.9
Residential or Domestic Customers....millions	38.9	45.8	51.4	57.6	64.0	65.7	67.3	69.4	71.0	72.6
Aug. KWH Used per Customer (Total)...1,000	6.4	9.3	11.7	14.7	19.4	20.0	21.0	22.0	21.4	21.5
Aug. KWH Used per Customer (Residential).....1,000	1.8	2.8	3.9	4.9	7.1	7.4	7.7	8.1	7.9	8.2

*Source: Statistical Abstract of the United States,1975

#Estimated by "1976 Annual Statistical Report," Electrical World, March 15, 1976

Table 4-3 shows a record of average annual electricity bill from 1965 to 1975. The average annual residential bill in 1975 increased by $44 to $268 for a 19.8% increase over 1974. This increase is higher than in 1974, when the annual bill increased by $31.49 or 16.4%.

The average cost per KWH hit a new high in 1975, when it rose 0.42¢ to 3.25¢. This was a 14.8% increase over 1974. The cost per KWH hasn't been this high since shortly after the end of World War II-30 years ago. Last year's average-cost rise, however, was slightly less than in 1974, when it was 0.45¢ or 19%.

4.3.2 Current and Projected Trends

Electricity and gas are the two basic sources of energy in most any household. The increase in cost of these two sources of energy reflects not only the increasing demand, but also the rapid consumption of other energy resources.

A 1973 report by a National Gas Survey Task Force to the Federal Power Commission contains a projection of residential gas and electricity price increases from 1970 to 1980. The country was divided into 11 regional market areas, one being the state of Oklahoma, Kansas, and Missouri. For this area, the study projected a 70% increase in natural gas costs to the consumer between 1970 and 1980, compared to a 40% increase in retail electric energy rates during the same period. The projection of gas and electrical costs is presented as a graph form in Fig.4-3.

A study conducted by Westinghouse Electric Corporation tends to concur with this prediction. While the Task Force projection was concerned with

TABLE 4-3 AVERAGE ANNUAL ELECTRICITY BILL*

CLASS / AVG BILL PER KWH or annual / YEAR	1965 KWH	1965 Annual	1970 KWH	1970 Annual	1971 KWH	1971 Annual	1972 KWH	1972 Annual	1973 KWH	1973 Annual	1974 KWH	1974 Annual	1975 KWH	1975 Annual
Total ultimate customers:	1.59¢	$234	1.59¢	$308	1.69¢	337	1.77¢	$371	1.86¢	$408	2.30¢	$493	2.76¢	$592
Residential Use	2.25¢	$111	2.10¢	$148	2.19¢	$162	2.29¢	$176	2.38¢	$192	2.83¢	$224	3.25¢	$268
Large light & power	0.90¢	$12,426	0.95¢	$15,504	1.03¢	$17,222	1.09¢	$19,204	1.17¢	$20,529	1.55¢	$25,562	1.99¢	$31,257
Small light & power	21.3¢	$584	2.01¢	$803	2.12¢	$889	2.22¢	$988	2.30¢	$1,094	2.85¢	$1,327	3.27¢	$1,612

*Source: 1976 Statistical Report, Electrical World, March 15, 1976

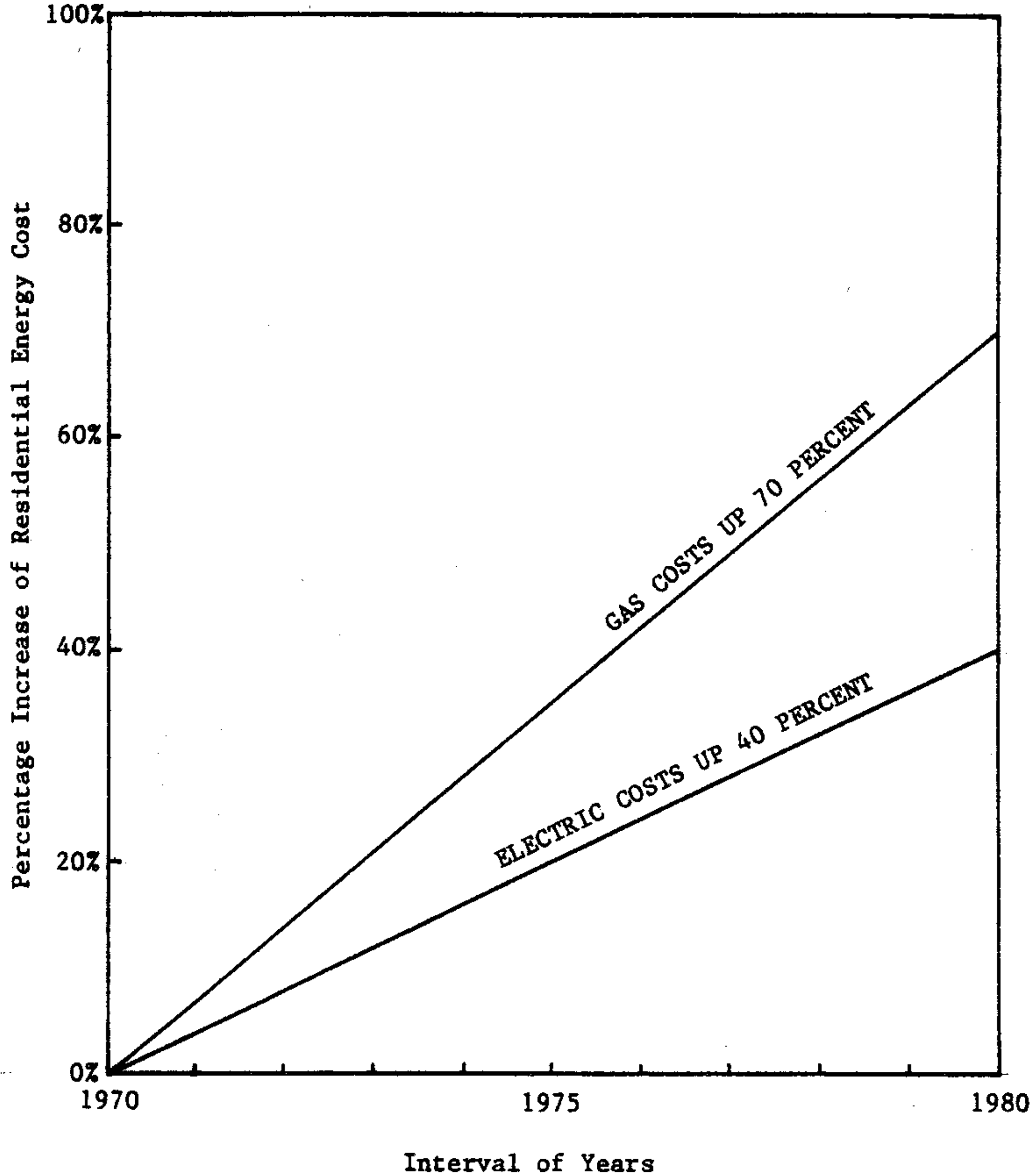

Fig. 4-3 Projections of Gas and Electric Costs (1970-1980)*

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*Source: National Gas Survey Task Force Report to Federal Power Commission, 1973 fuel cost only, the Westinghouse projection includes other factors but shows that retail gas costs are rising more than twice as fast as electricity.

Fig. 4-4 shows the Westinghouse projection of five different types of home space conditioning systems based strictly on increased fuel prices. Gas was figured at 10 cents per therm with prices doubling by 1975, tripling by 1980 and continuing to increase at the latter rate. Electricity was anchored at a 1.25 cents per KWH base and projected to double by 1985.

As the Task Force projection was based on fuel costs for Kansas, Missouri, and Oklahoma, the rates for residential customers of major utility companies in three-state areas were averaged. Fig. 4-5 shows a definite trend toward the projection.

From the cost trends just presented, the increase in the burden on the household budget for energy consumption is foreseeable.

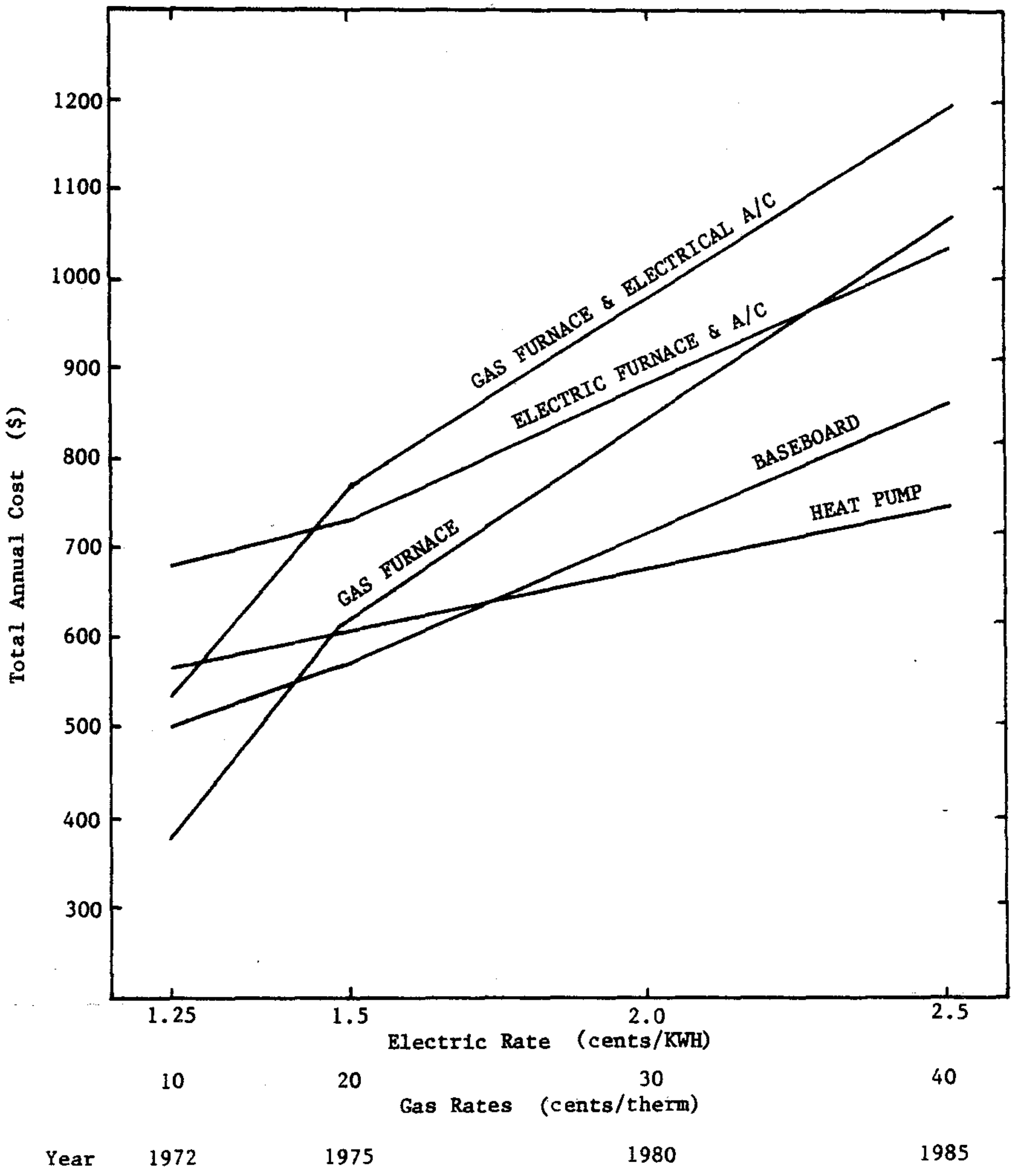

Fig. 4-4 Comparison of Alternate Systems Costs Heating Annual Fuel, Depreciation, and Maintenance Capital (including owing cost of A/C)*

* Source: Westinghouse Electric Corporation Report, 1975

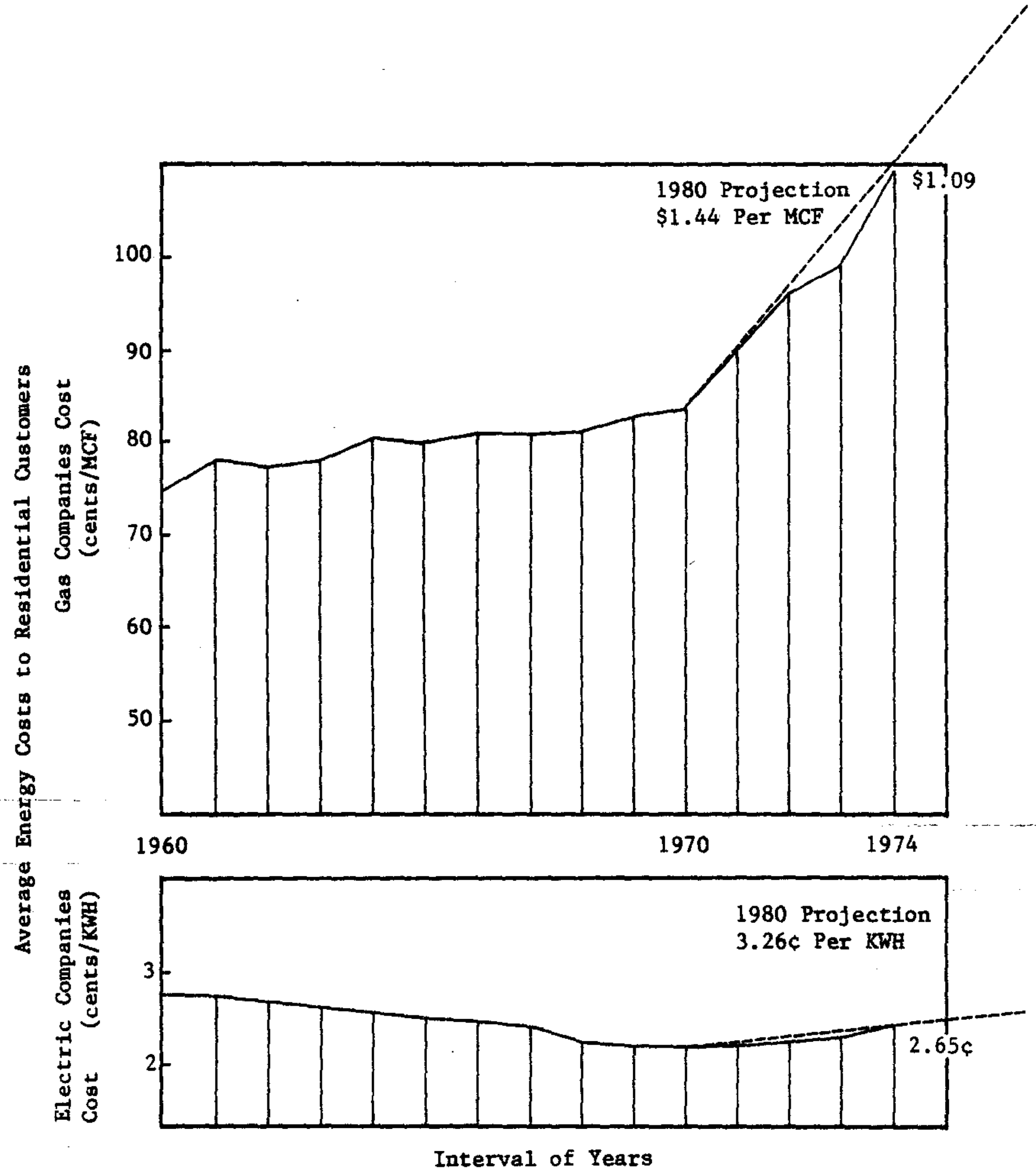

Fig. 4-5 Trends of Average Energy Costs to Residential Customers (1960-74)*

*Source: Kansas-Missouri-Oklahoma Utilities Annual Report, National gas Survey Task Force, 1975

CHAPTER V

ENERGY CONSUMPTION FOR CONVENTIONAL WATER PRODUCTION AND WASTEWATER TREATMENT IN U.S.

5.1 Energy Consumption for Water Production

In the wake of the energy crisis that has confronted scientists and researchers today, substantial reports on energy consumption for water treatment, transmission or distribution for aiding conservation of energy are still eminently absent. In this study, a cost figure for energy consumed in water treatment process is required as well as that form of energy conserved in operating a water conservation device.

Koenig, in his 1967 report, had presented a detailed investigation and analysis of the costs of a water treatment plant and other operating installations (11). Section 5.1.1 to 5.1.4 contain a modified summary of electricity, oil, and gas consumed in each treatment process, as reported by Koenig.

Among all types of water treatment plants in the United States , the major class comprising simple disinfection are the most numerous (7). However, it was believed that the study of energy consumption would be more fruitful if it were applied to the second most populous major class, namely, that having coagulation, sedimentation, and rapid sand filtration. Within this class, though, there are still various combinations of equipment or process types.

5.1.1 Unit Prices, Consumptions and Costs of Energy Used in Sampled Plants

The electric energy unit consumptions include plant lighting and heating where the latter was by electricity. This energy is small compared to pumping energy, and it is usually not possible to separate them out. Oil and gas consumption was primarily for heating.

The study conducted by Koenig produced 30 usable interviews in all sizes water treatment plants. It is a little over a 5 percent sample for the small size plants and a little over 12 percent for the large ones.

Table 5-1 and 5-2 present the reduced data of unit energy prices and consumptions for each water treatment plant in Koenig's report. Plant No. 11, 16, and 20 are missing, because although interviewed, they did not provide data suitable for the study. In Table 5-2, the last column titled "Backwash Energy Consumption" is a figure computed per million gallons of raw water from the discharge pressure on the pump supplying the backwash water. This may be either pumping to storage, pumping directly for backwash, or withdrawing at highline pressure. It was necessary to make special measurements of this discharge pressure at a number of plants since it is not a regular datum. The computed energy was adjusted upward assuming a 70 percent wire-to-water efficiency to make it comparable with metered kilowatt-hour figures. It is because that, in Koenig's survey, only one plant had a kilowatt-hour meter on the backwash pump.

Table 5-3 shows the average unit cost of energy used in the 27 sampling plants. The figures marked with stars are the missing data which were not provided suitably by the interviewed plants.

TABLE 5-1 UNIT PRICES OF ENERGY USED IN WATER TREATMENT PLANTS

Unit Prices / Energy Type / Plant No.	Electricity ¢/KWH	Oil (for heating) ¢/gal	Gas (for heating) ¢/Kcf*
1	0.92	-	-
2	0.77	-	-
3	1.70	-	33.3
4	1.00	-	-
5	1.40	-	-
6	1.40	-	-
7	1.00	-	-
8	2.00	-	-
9	1.04	-	-
10	2.00	-	-
12	1.00	-	-
13	1.30	-	-
14	1.90	15	-
15	0.77	9.6	705#
17	0.69	10.5	-
18	2.00	16.9	-
19	0.91	9.9	-
21	0.89	-	76
22	0.70	-	-
23	1.33	-	-
24	-	-	-
25	-	-	-
26	1.20	-	-
27	1.20	-	-
28	1.04	-	30
29	0.91	-	47
30	0.70	-	-

* Kcf = Thousands of cubic feet

Plant use LPG (Liquified Petroleum Gas) and prices are per liquid cubic foot.

Source: 11

TABLE 5-2 UNIT CONSUMPTION OF ENERGY USED IN WATER TREATMENT PLANTS

Unit Consumption / Energy Type	Electricity					
Plant No.	Total KWH/ Kgal	Raw Water KWH/ Kgal	Finished Water KWH/Kgal	Oil gal/mg*	Gas K_{cf}/mg	Backwash KWH/mg Raw water
1	1.73[a]	-	-	-	-	-
2	2.46	-	-	-	-	3.8
3	0.33[b]	-	-	-	5.47	-
4	2.04	1.26	0.78	-	-	9.1
5	2.33	0.94	1.39	-	-	-
6	2.5[c]	-	-	-	-	-
7	3.25	1.29	1.96	-	-	2.6
8	2.15	-	-	-	-	2.4
9	3.27	-	-	-	-	-
10	2.39	-	-	-	-	0[d]
12	1.42	-	-	-	-	-
13	1.32	-	-	-	-	-
14	2.37	-	-	119	-	-
15	2.32	0.41	1.91	23.1	0.005	39
17	1.41	0.70	0.71	11	-	7.0
18	1.60	-	-	27	-	-
19	0.82	-	-	18	-	4.6
21	3.03	-	-	-	1.41[e]	4.7
22	2.89	-	-	-	-	45
23	-	-	-	-	-	19
24	-	-	-	-	-	4.6
25	-	-	-	-	-	14
26	3.60	-	-	-	-	54
27	1.22	-	-	-	-	16
28	2.78	1.11	1.68	-	2.3	-
29	1.72	0.82	0.45	-	0.4	3.8
30	1.65	-	-	-	-	19

*mg = million gallons

a. Plant is operated in parallel with a softening plant. Unit consumption given is for total operation

b. Plant uses gas engine regularly and electric energy for peaking.

c. Based on one month only.

d. Automatic backwash and gravity raw water supply.

e. This gas used for recarbonation, not heating.

Source: 11

TABLE 5-3 AVERAGE UNIT COST OF ENERGY USED FOR PERIOD IN WATER TREATMENT PLANT

Avg. Unit Cost / Energy Type / Plant No.	Total ¢/kgal of $\bar{Q}$#	Pumping ¢/kgal of $\bar{Q}$	Heating ¢/kgal of $\bar{Q}$	Heating ¢/kgal of $\bar{Q}d$#
1	1.59	1.59	-	-
2	1.89	1.89	-	-
3	0.74	0.74	-	-
4	2.04	2.04	-	-
5	3.26	3.26	-	-
6	3.50	3.50	-	-
7	3.25	3.25	-	-
8	4.30	4.30	-	-
9	3.90	3.90	-	-
10	4.90	4.80	0.15*	0.04*
12	1.45	1.42	0.03*	0.03*
13	1.81	1.72	0.09*	0.04*
14	6.41	4.63	1.78	0.82
15	2.01	1.79	0.22	0.09
17	1.08	0.97	0.11	0.08
18	3.80	3.20	0.58	0.32
19	0.93	0.75	0.18	0.13
21	2.68	2.68	-	-
22	2.02	2.02	-	-
23	-	-	-	-
24	-	-	0.01	0.006
25	-	-	-	-
26	4.30	4.30	-	-
27	1.46	1.46	-	-
28	2.96	2.89	0.07	0.02
29	1.63	1.61	0.02	0.01
30	1.15	1.15	-	-

$\bar{Q}$ = Average raw water intake, mgd

$\bar{Q}d$ = Designed capability for raw water, mgd

*Missing data supplied as described in text.

Source: 11

5.1.2 Distributions of Energy Prices, Consumptions and Costs in Sampled Plants

The comparative data on the unit prices, consumptions and costs of energy used in the 27 water treatment plants are summarized in Table 5-4. The original information was used in Koenig's report to allow individual plants to assess their performance relative to other plants in terms of the percentile level which they hold among all plants.

In this study, the itemized listing of the various energy uses can assist in understanding the distribution of each categorical energy use. In Table 5-4, the values at 50 per cent is the average value of energy consumption of water production calculated in Chapter VII. The column of the no. of points is the number of appearances of data in each column in Table 5-2, 5-3 and 5-4. The no. of points is actually the plotting points used in distribution analysis.

The readings from the straight lines at the 10 percentile, the 50 percentile, and at the 90 percentile levels are shown on the table in sequence. The 10 percentile value is that above which lies 90 percent of the plants and below which lies 10 percent. For instance, if an individual plant has a unit oil consumption of 9.5 gal/mg, which coincides with the 10 percentile level in the table, it means that 90 percent of the plants have their unit oil consumptions greater than 9.5 gal/mg. The 50 percentile level, or median level, is that value of the factor above which lies 50 percent of the plants and below which lies the other 50 percent. The values at the column of 50 percentile level are the approximate figures used in Chapter VII.

TABLE 5-4 DISTRIBUTION OF UNIT PRICES, UNIT CONSUMPTIONS AND UNIT COSTS

Item	No. of Points	Distribution Typy	Value of Factor at Indicated Percentage 10%	50%	90%	Variance (σ Ratio)
Unit prices:						
Electrical energy, (L*)-¢/KWH	14	log	0.65	0.92	1.30	1.32
Electrical energy, (S*)-¢/KWH	11	log	0.98	1.48	2.22	1.36
Oil-¢/gal	5	log	9.80	12.00	18.20	1.40
Unit consumptions:						
Pumping energy, (L)- KWH/mg	14	log	9.80	1,800	3,270	1.59
Pumping energy, (S)-KWH/mg	10	log	1,440	2,250	3,500	1.42
Raw water energy (L)-KWH/mg	4	log	310	740	1,750	1.96
Raw water energy (S)-KWH/mg	3	log	820	1,100	1,500	1.27
Finished water energy (L)-KWH/mg	4	log	640	900	1,290	1.32
Finished water energy (S) KWH/mg	3	log	970	1,350	1,950	1.33
Oil-gal/mg	5	log	9.5	21	48	1.90
Backwash energy-KWH/mg	18	log	2.1	10	48	3.40
Unit costs:						
Pumping energy (Large)-¢/kgal	14	log	0.80	1.57	3.10	1.97
Pumping energy (Small)-¢/kgal	10	log	2.40	3.45	5.05	1.34
Heating	-	-	-	-	-	-

*L = maximum charge   S = minimum charge

Source: 11

The σ ratio, which measures the variance of the data points, are listed on the last column. It is the ratio of the value at one standard deviation from the median or at one standard error of estimate from the regression line to the value at a median. The main purpose of the σ ratio in the table is to show the general extent of the dispersion.

For purchases, unit prices of energy used in the plants are greater for the smaller plants, indicating the savings in bulk purchases. Among the various categories of unit consumptions, it is noted that the pumping energy for small plants is greater than that for large plants, and the difference is of a magnitude as to be unmistakable. In the median the differences are of the order of 25 percent for total pumping energy and 40-50 percent for raw water and finished water energy separately. This difference, according to Koenig's report, suggests that the smaller plants tend to have higher TDH (total dynamic head) and lower pumping efficiency than the larger plants. Physically, one can well imagine that the larger cities tend to be located closer to the elevation of their water sources than do the small cities. At least very few larger towns are located at high altitudes in regions of high relief. Also, if the pipelines in the sample are optimized, the optimum friction head for higher capacities is substantially lower than that for lower capacities.

Unit costs of energy used in the plants are a product of unit prices and unit consumptions. Unit prices and consumptions both tend to be higher in the smaller plants so that the unit costs are higher in the smaller plants.

Distribution of heating costs are not shown in Table 5-4 because they have a rational correlation with climate. In the South, heating costs were so small that they could not be separately determined. Heating costs are no doubt correlatable with design capability for raw water (Q_d) and with the standard heating degree-days. It may also be compared on the basis of the climate measure already used, namely, average number of days below 32°F. Where days below 32°F were 60-80, heating costs were of the order of 0.01-0.02 ¢/Kgal of Q_d. Heating costs below 80 days may thus be considered as 9 ¢/Kgal. Koenig reported that five of the plants in the 140-day climatic zone showed heating costs of about 0.1 ¢/Kgal of Q_d for the large plants and 0.3 and 0.8 ¢/Kgal for the small plants.

5.1.3 Contribution of Energy Cost in Typical Plants and Best Plants

To provide a general view of the contribution of ¢/Kgal energy cost a computation has been made for "typical" plants in two size categories, standardized as Q_d's of 0.5 and 8.0 mgd, and at a utilization factor 0.5. The size of 0.5 mgd approximates the median capability of B-type* plants in the United States. The 8.0 mgd approximates the estimated median capability of all 18,000 U.S. water utilities where median in this case signifies the median with respect to the total amount of water produced. The utilization factor $\bar{U}$ is the ratio of the average daily raw water intake

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* B-type plants are the sampled ones which used alum but no other coagulant; which had certain types of mixing devices and certain types of sedimentation basins; which disinfected with chlorine; which did not employ aeration, ammoniation, or recarbonation; which were not listed as using chemicals for erosion control; and which, if they used chemicals for taste and odor control, used only carbon.

to the daily raw water capability.

The typical plant is one which has the median value for each cost component, i.e., investment, manpower, energy, chemicals, etc., and has a Q_d of 0.5 or 8.0. The contribution of energy cost in typical plants is shown in Table 5-5.

It should be noted that the heating cost is about the maximum heating cost to be experienced in the United States. In the South heating cost would be zero. The contribution of energy cost is ranked below the investment and manpower and with about 10-13 percent contribution.

It happens that the energy consumption shows considerable dispersion among the 27 sampled plants. The "best" plants, therefore, are considered as the ones which have operated in investment and manpower at a level achieved by the 10 percentile plant. The results of contribution of energy cost are also shown in Table 5-5.

It is seen that if the figures for investment and manpower are those of the 10 percentile plants, the energy cost contributes 16-21 percent of total cost. This is 6-8 percent elevation from the typical plants'.

5.1.4 Energy Cost Estimate

It has been shown that energy is the third major contribution to the total cost of water treatment and the distribution data have shown that the variance in unit energy is high. For example, between the 10 percentile and the 90 percentile level unit energy consumption can vary three-fold in large or small plants. This means that even if the unit energy prices were the same for all plants, no estimating method based on the data from the present study could be expected to provide suitable estimates

TABLE 5-5 CONTRIBUTION OF ENERGY COST IN TYPICAL PLANTS AND BEST PLANTS

Unit Cost / Item \ Q_d, mgd / U / Unit	0.5				8.0			
	0.5		1.0		0.5		1.0	
	¢/kgal	%	¢/kgal	%	¢/kgal	%	¢/kgal	%
"Typical Plants"								
Energy Cost	3.30	10.6	3.30	15.7	1.70	13.6	1.70	22.1
Heating cost (140 day)	0.92	3.0	0.46	2.2	0.22	1.8	0.11	1.4
Other costs	26.87	86.4	17.26	82.1	10.53	84.6	5.90	76.5
Total	31.09	100	21.02	100	12.45	100	7.71	100
"Best Plants"								
Energy cost (50%)	3.30	16.3	-	-	1.70	21.1	-	-
Heating cost (50%) (140 day)	0.92	4.6	-	-	0.22	2.7	-	-
Other costs	15.98	79.1	-	-	7.91	76.2	-	-
Total	20.20	100	-	-	9.83	100	-	-

*Source: 11

for the energy costs for a particular water treatment operation. However, it is possible with a considerable degree of accuracy to estimate the average energy cost for a reasonable number of identical plants.

Assuming that the errors due to variances in unit energy consumption have been averaged out, there still remains a number of parameters which influence the costs of treatment. Among these are the temporal and regional price levels which can be adjusted by suitable cost indexes. Another such parameter is the unit prices for energy, which also can be allowed for in some degree by means of indexes.

The estimated energy costs can be adjusted in accordance with the details of any set of parameters described in pervious sections. As an example, Table 5-4 shows that median unit consumption of pumping energy in large plants is 1,800 KWH/mg, while the median unit price of electrical energy in large plants is 0.92 ¢/KWH. Roughly, one would expect that the unit cost of pumping energy in large plants would be

$$1{,}800 \text{ KWH/mg} \times 0.92 \text{ ¢/KWH} = 1{,}656 \text{ ¢/mg or } 1.66\text{¢/Kgal}$$

Table 5-4 shows, indeed, that the median unit cost for pumping energy in lage plants is 1.57 ¢/Kgal.

If we wish to estimate for a higher energy price region where unit price were say 1.00 ¢/KWH, the unit cost would be approximately

$$.57 \text{ ¢/Kgal} \times \frac{1.00}{0.92} = 1.70 \text{ ¢/Kgal}$$

The unit energy and heating cost of fully utilized capability ($\bar{U} = 1$) in typical large plants ($Q_d = 8.0$), which was shown in Table 5-5, will be used as a basis of unit energy cost in water treatment plant in Chapter VII. The calculation is as follows:

Unit energy cost in water treatment plant

= Energy cost (elec.) + Heating cost (oil and gas)

= 1.70 ¢/Kgal + 0.11 ¢/Kgal

= 1.81 ¢/Kgal

The reason for using such a figure is that it appeared to be a relatively minimum number compared to the other combinations in Table 5-5. When used as a calculation basis, consequently, it is a most conservative figure.

5.2 Energy Consumption for Wastewater Treatment

5.2.1 Energy Consumption for Conventional Processes

The estimate of electrical power consumption for conventional processes of primary, trickling filter, and activated sludge wastewater treatment plants has been made by E.P.A. in 1973 (22). A complete list of total energy consumption for seven different plants with three plant sizes, respectively, was compiled in Table 5-6. The figures shown on the table were estimated by adding electrical power requirements for individual processes and various plant utilities. The sludge handling schemes selected in E.P.A.'s report are shown in Appendix A.

Total electrical power consumptions for plants taken from Table 5-6 are then plotted versus plant size in Fig. 5-1. Energy consumption for activated sludge plants is almost linear with plant size because influent pumping and diffuses air consumption are the major uses and these are

TABLE 5-6 ELECTRICAL ENERGY CONSUMPTION OF CONVENTIONAL WASTEWATER TREATMENT PLANTS*

TYPE OF PLANT	SLUDGE HANDLING SCHEME#	ENERGY CONSUMPTION (KWH/day) PLANT SIZE 1 mgd	10 mgd	100 mgd
Primary Plant	I	372	2,293	18,700
	II	411	2,343	21,000
Activated Sludge Plant	I	1,004	8,218	75,864
	II	1,115	8,809	81,094
	III	1,085	9,044	85,862
Trickling Filter Plant (High Rate)	I	610	4,215	35,052
	II	721	4,806	40,282

#See Appendix A

*Source: EPA-R2-73-281, "Electrical Power Consumption for Municipal Wastewater Treatment," 1973

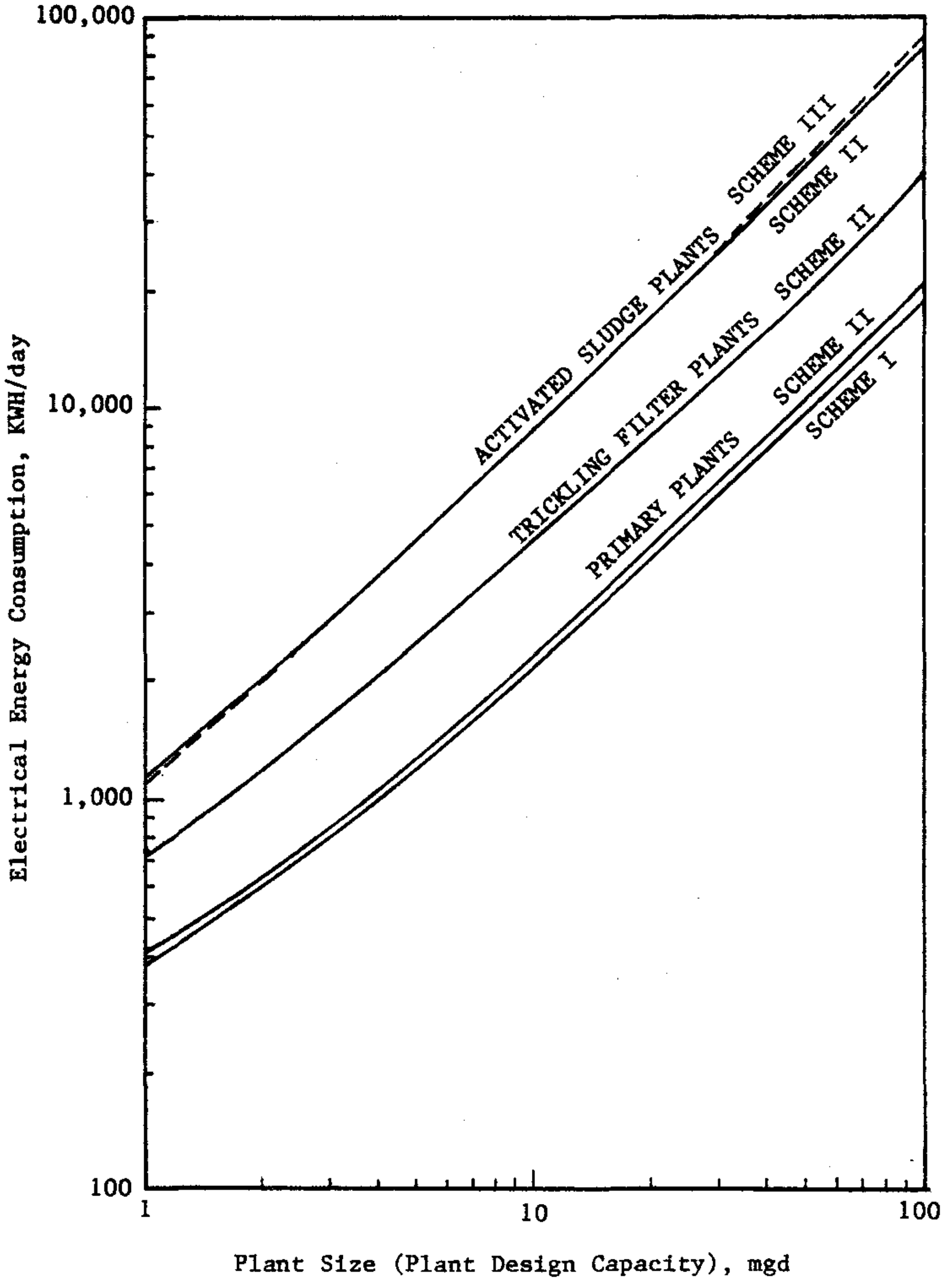

Fig. 5-1 Electrical Energy Consumption in Conventional Wastewater Treatment Plants vs. Plant Size*

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*Source: EPA-R2-73-281, "Electrical Power Consumption for Municipal Wastewater Treatment", 1973 linear with the volume of the main stream. The curves for primary and trickling filter plants shown significant economy of scale.

5.2.2 Cost of Energy Consumption in Conventional Plants.

The cost of electrical energy used in wastewater treatment plants depends on the peak demand for power as well as the amount of kilowatt-hours used. The average cost of electricity in U.S. has been shown in Table 4-3. The average bill of large light and power in 1975, for instance, is 1.99 cents per KWH. In E.P.A.'s report, these figures have been used to compute the monthly and yearly expenditure for electrical energy of the seven plant types shown in Table 5-6. The dollar amounts per thousand gallon treated wastewater are summarized in Table 5-7. These values have been converted to dollars per year and plotted in Fig. 5-2.

5.2.3 Comparison of Energy Consumed in Various Plants

The estimated energy consumptions for wastewater treatment plants, based on the 1968 Inventory of Municipal Waste Facilities, are shown in Table 5-8. The average electricity usage was 0.0573 KWH/day/capita. This amount of power consumed in wastewater treatment is only about 1% of the average residential consumption of electrical power. It is about the equivalent to one 8 watt bulb in each household, burning 24 hours per day (22).

If all of the population was served by activated sludge plants, the power consumption would be about 0.1130 KWH/day/capita which is equivalent to a 15 watt light bulb burning in each household 24 hours per day.

TABLE 5-7 COST OF ELECTRICAL ENERGY CONSUMPTION OF CONVENTIONAL WASTEWATER TREATMENT PLANTS*

TYPE OF PLANT	SLUDGE HANDLING SCHEME#	COST OF ENERGY CONSUMED (Cents/kgal treated) PLANT SIZE: 1 mgd	10 mgd	100 mgd
Primary Plant	I	0.720	0.338	0.224
	II	0.756	0.344	0.250
	Avg.	0.738	0.341	0.237
Activated Sludge Plant	I	NA	NA	NA
	II	2.070	1.220	0.997
	III	2.010	1.250	1.030
	Avg.	2.040	1.235	1.004
Trickling Filter Plant (High Rate)	I	NA	NA	NA
	II	1.400	0.660	0.472
	Avg.	1.400	0.660	0.472

See Appendix A

*Source: Same as Table 5-6

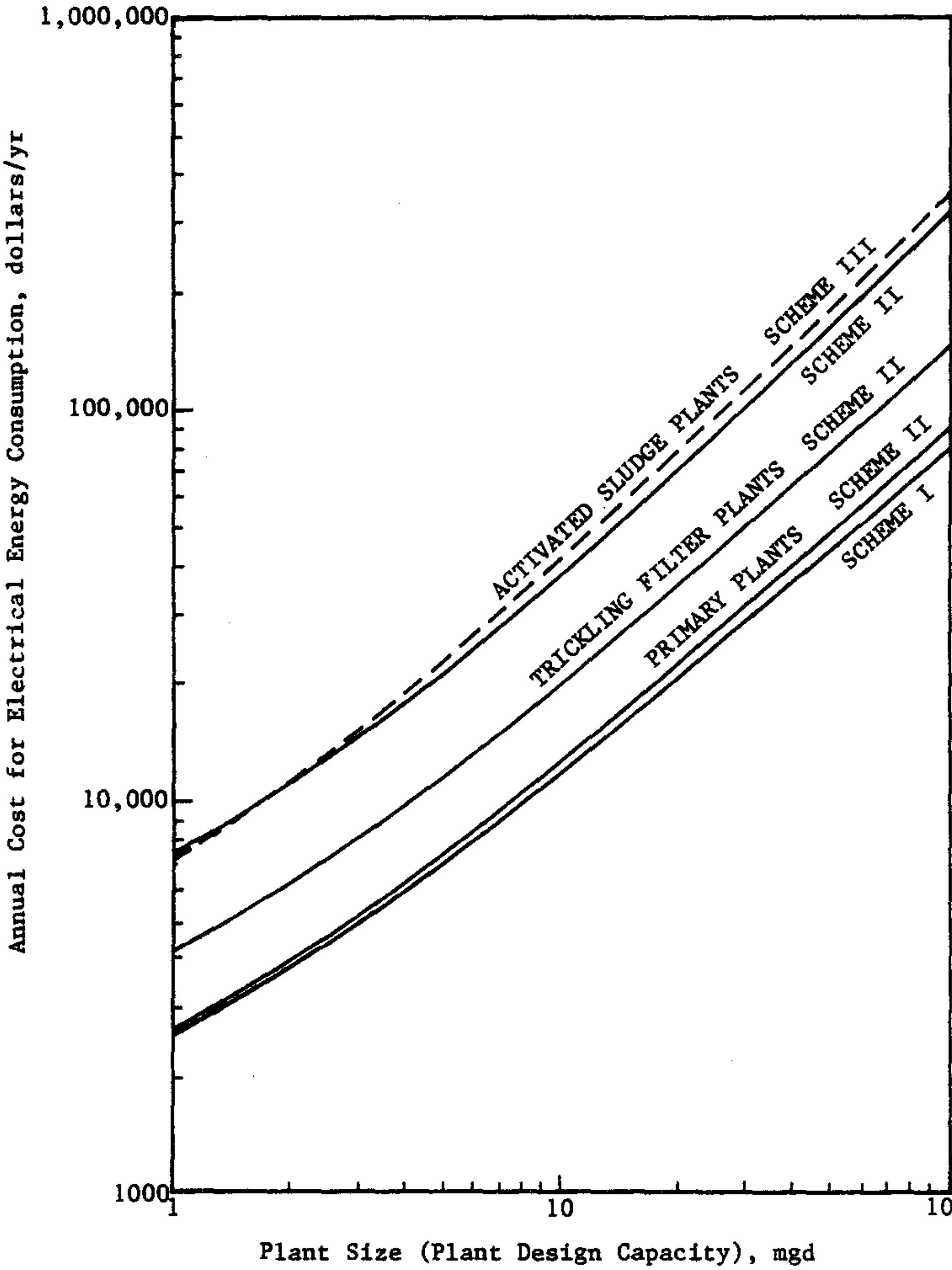


Fig. 5-2 Annual Expenditure for Electrical Energy Consumption in Conventional Wastewater Treatment Plants vs. Plant Size*

*Source: Same as Fig. 5-1

TABLE 5-8 FACTS OF ELECTRICAL ENERGY CONSUMPTION IN WASTEWATER TREATMENT PLANTS (BASED ON THE 1968 INVENTORY OF MUNICIPAL WASTE FACILITIES)*

FACILITY	POPULATION SERVED	WASTEWATER (gpd/capita)	ENERGY CONSUMPTION (KWH/day/capita)	ENERGY CONSUMPTION (KWH/day)	PROPORTION OF CONVENTIONAL PLANTS
Conventional:					
Primary Treatment	36,947,397	122	0.0286	1,056,696	15.1%
Activated Sludge	41,264,036	123	0.1130	4,662,836	66.7%
Trickling Filters	29,617,136	89	0.0430	1,273,537	18.2%
Minor Treatment	1,360,870	122	0.0185	25,176	-
Intermediate Treatment	5,857,690	122	0.0286	167,530	-
Ponds	6,123,078	89	0.0135	82,662	-
Other and Unknown	8,636,514	89	0.0135	116,593	-
Tertiary Treatment	325,530	123	0.2260	73,570	-
TOTAL	130,132,251		(Avg.=0.0573)	7,458,600	100%

*Source: EPA-R2-73-281, "Electrical Power Consumption for Municipal Wastewater Treatment," 1973

Power consumption for tertiary wastewater treatment is highly dependent on the train of process selected. For train V the power consumption is roughly equivalent to the activated sludge process. While the power consumption of train VIII is about 40-50% greater than activated sludge. Thus, if we assume the using of train III or V, the consumption of power per household would be roughly equivalent to a 30 watt desk lamp burning for 24 hour/day.

5.2.4 Energy Cost estimate

In estimating a water conservation device's saving in energy, a figure is first needed on the cost of energy consumed in wastewater treatment process. In Table 5-8, more than seven types of facilities are listed for wastewater treatment. Among them, three conventional plants served 82.9% of the entire population, while other facility types are used only at very localized special areas. Thus, in estimating the average figures from the three conventional facilities are used.

Method of calculation is as follows:

In Table 5-7, the three average costs of energy consumed (0.237, 1,004 and 0.472) by plants of size 100 mgd are chosen as basis for estimation. The criteria of this is that the energy consumption per unit product of this size plant is relatively less and in estimating water conservation devices, they tend to yield more conservative cost figures.

In Table 5-8, the proportion of energy consumption of primary treatment, activated sludge and trickling filters are respectively 15.1%, 66.7% and 18.2%. Multiply the average cost by their relative percentage weight, summed, then the final average cost can be obtained.

$$0.237 \times 15.1\% + 1.004 \times 66.7\% + 0.472 \times 18.2\%$$

$$= 0.7914 \text{ cents/Kgal wastewater treated}$$

The figure of 0.7914 cents/Kgal obtained here is the average cost of energy consumption for wastewater treatment required in Chapter VII.

CHAPTER VI

A SURVEY OF WATER CONSERVATION ALTERNATIVES

As mentioned in the previous chapter, water use in this nation has increased substantially faster than its population. This causes the increase in energy required to clean, pump, treat and heat water. Emerging concern for reduction in water consumption has been shown in order to save both water and energy.

Water use reduction can be accomplished through reduction in household water use, industrial waste water recycle/reuse, and realistic economic policies. This study only deals with reduction in household water use. This chapter is a survey of the availability of household hardware devices that have the potential of reducing water consumption. Four major categories are included: water conservation toilet insert devices and systems, faucet flow reduction devices, water recycling systems, and other water conservation appliances. They are discussed in the following sections.

6.1 Waste Disposal Systems

In this study, waste disposal systems are classified according to the treatment processes. The major categories include infiltration, removal, destruction and decomposition.

Infiltration refers to absorption and dispersion of excreta in the soil and ground water. Removal methods include those where the excreta is transported manually, by vehicle, or by means of pipes, to be disposed of in sewage oxidation ponds, bodies of water or to be processed further. Destruction refers to those methods where the excreta are destroyed by combustion. Decomposition methods include those which require micro-biological action. These systems along with household waste treatment plants are described and discussed as follows.

6.1.1 Infiltration

This is the oldest method of waste disposal and still probably the most widespread. The waste is fermented in a pit and infiltrated into the soil. This process can take place with or without water. There are three cases where infiltration can not be used: extreme cold, low-porosity soil, and high population density. Three different kinds of systems are categorized under infiltration methods: pit latrine, aqua privy and septic tank.

a. Pit Latrine

Description: Pit latrine consists of hole covered with a squatting plate or a seat. The liquid wastes infiltrates into the ground, and the solid wastes accumulate in the pit, and decomposed.

Advantage: least expensive system

Disadvantages: 1) not suitable for heavy use.

2) slow process of purification and pollution of surrounding soil.

b. Aqua Privy

Description: It consists of a tank with a constant water level. The tank is sometimes divided into 2 or 3 compartments. A pipe extends from toilet seat to waste water surface. Certain quantity of water is added to the tank when flushing. This moves the waste from the first (anaerobic) compartment to the second one (aerobic). The liquids in tank overflow into soakage or leaching pits, and is absorbed by the soil. The solids must be removed after a certain period of time.

Advantage: water-saving. Some system uses only 1.5 gallons of water per capita per day.

Disadvantages: can be used only at the places where soil absorption capacity is high and where there is no danger of ground water pollution.

c. Septic Tank

Description: This system is essentially an aqua privy, except that the toilet seat is not located directly on top of the tank, but some distances from it. Waste is carried to the tank by water through pipes.

Disadvantages: much greater use of water than aqua privy, about 25 gallons per capita per day.

6.1.2 Manual Removal

If infiltration can not be used because of cold, soil type and high population density, the most common method is to manually remove the waste to a distant leaching pit or sewage lagoon. Chemicals are often used to reduce smell and danger of contamination before the waste is disposed. Water is not usually used in these systems. There are five different systems of this type: bucket, chemical toilet, freeze toilet, packing toilet, and recirculating chemical toilet.

a. Bucket

Description: This is a traditional system, known for many years and still in use. It consists of a bucket in which waste is deposited, and which is removed and cleaned at intervals.

Advantage: 1) uses no water 2) low cost

Disadvantage: there is a health hazard when handling and emptying the bucket.

b. Chemical Toilet

Description: It is essentially a bucket toilet to which are added chemicals which reduce the rate of biological decomposition and reduced odors.

Advantages:
1) uses no or little (1.5 gallons per capita per day) water
2) low initial cost

Disadvantages:
1) cost of chemical is relatively high
2) disposal of the waste may cause pollution of river or groundwater
3) not suitable for high population density area
4) uses potentially dangerous chemicals

c. Freeze Toilet

Description: This type of toilet is a bucket toilet where the waste falls into a plastic bag which is refrigerated

Advantages: 1) no water needed

2) no health hazard

3) low operating cost (in Sewden, US $0.02-0.03/day)

Disadvantages: 1) high initial cost

2) energy such as electricity or gas required

d. Packing Toilet:

Description: This is another refinement of bucket toilet. The waste is sealed in a plastic bag after each use and has to be emptied at intervals.

Advantages: 1) no water required

2) no health hazard

Disadvantages: 1) high initial cost

2) energy required

e. Recirculating Chemical Toilet

Description: This is a modified chemical toilet which contains a pump that recirculates the contents of tank for flushing. The chemicals liquify the solid waste, inhibit biological decomposition, and colorize the liquid.

Advantages: uses little water

Disadvantages: 1) high cost

2) requires electric power

3) disposal of the waste may cause river pollution

6.1.3 Mechanical Removal

The uses of infiltration and manual removal waste systems are not suitable for the areas with high population density, as the disposal point (river, sea or treatment plant) is too far away. However, the concentration of people and resources permits a large capital investment in networks (roads, sewers, water supply); therefore, mechanical means of removing the waste from the dwelling are employed. Usually, large amounts of water are required.

a. Privy Vault (or Vacuum Truck)

Description: The toilet is located directly above a ventilated steel tank, or concrete vault. Waste falls directly into the tank, and is collected at frequent intervals by a vacuum truck which sucks out the contents of the tank.

Advantages: 1) uses neither water nor chemicals

2) low initial cost

Disadvantages: 1) high operating cost

2) relies on good road network and specially designed trucks

3) odor problem when emptying the tank

re

b. Chemical Privy

Description: It is essentially a privy vault except that chemicals are used to kill bacteria, inhibit decomposition, and liquify most of the solids. The contents of the tank can be pumped out with any inexpensive pump.

Advantages: low initial cost

Disadvantages: 1) high operating cost

2) health hazard and odor problem when emptying the tank

3) requires chemicals, water and energy

c. Recirculating Fluid Toilet

Description: This system consists of flush toilets connected to a water-tight tank. Instead of water, fluid that does not mix with the waste is used for flushing. The waste and the fluid are separated at the tank, and the fluid is used again for flushing.

Advantages: neither water nor chemical required

Disadvantages: 1) high cost

2) requires energy

d. Water-borne Network

Description: It consists of flush toilets connected to a pipe network which transfers the wastes to the discharge point (river, lake, sea, or treatment plant). Water is used to carry the wastes in the pipe network.

Advantages: no health hazard

Disadvantages: 1) high cost

2) requires water (125 gallons per use)

e. Vacuum Network

Description: This system consists of toilets, of special construction, connected to a pipe network in which a vacuum is created. Water (about 1.5 gallons per capita per day) is needed to transport the waste.

Advantages: 1) water-saving (1.5 gallons per capita per day)

2) no health hazard

Disadvantages: high cost

6.1.4 Destruction

Human waste, as well as animal waste has been used as fuel for ages. Recently, this method of disposing of waste has been applied in the form of incinerating toilets. This sanitary method requires no water, and the disadvantage is possible air pollution.

a. Incinerating Toilet

Description: It consists of a bowl with a combustion chamber below. A liner is used to absorb the liquid waste and is also incinerated. Fumes are vented to outside. The destruction is rapid, leaving only ashes which have to be removed periodically.

Advantages: 1) uses no water

2) destruction is safe and complete

Disadvantages: 1) requires energy (electricity, oil or propane gas)

2) possible air pollution

3) high initial and operating cost (5¢ per use in Canada)

6.1.5 Decomposition

All the above systems except destruction are anaerobic purefaction of waste. The disadvantage of those systems is that there is no oxygen present, no heat build-up occurs, and it takes up to 6 months to destroy pathogenic bacteria and other parasites. Decomposition is an alternative to these systems. In aerobic decomposition, the high temperature generated by the oxidation destroy the pathogens in hours. It is an efficient method of waste disposal, also provides fertilizers for agriculture uses.

a. Compost Privy

Description: It consists of a tank with an air intake and a ventilation duct. Human waste, paper, and organic kitchen refuse compose together into a fertilizer humus whose volume is about 10% of the original. There is an access door at the lowest point of the tank for removing the humus. A layer of straw, sawdust or leaves must first be placed on the bottom of the tank to absorb the liquid waste and air decomposition.

Advantages: 1) no water, chemicals or fuels required

2) valuable fertilizer produced

Disadvantages: high initial cost

b. Continuous Aeration

Description: This is a combination of decomposition and flush toilet. The waste is carried to one or two tanks where it is continuously aerated by means of an air pump. The aerated liquid is reused for flushing.

Advantages: 1) requires little water

2) no health hazard

Disadvantages: 1) odor problem when overused

2) consumes energy (for pump)

3) high initial and operating cost

c. Algae Digester

Description: This is a closed system for handling waste disposal and producing gas and fertilizer. It combines a compost privy with a solar heated algae tank and digester. Pathogens are destroyed by the ultra violet rays of the sun, and the algae break down the solids to produce gas and fertilizer.

Advantages and Disadvantages: unknown because this system is still in its experimental stage.

6.1.6 Household Waste Treatment Plants

The individual household treatment plant is usually used where pipe networks are not economic, and where septic tanks can not be used because of soil conditions. The plant is designed to treat waste, primarily through aerobic decomposition, settlement, and sometimes filtration. The output from such a plant is pure enough to be dischargod into river or soil without danger of pollution. It could also be reused for flushing. This type of plant require a large initial investment and continuous maintenance.

Total of sixty-eight different water conservation toilet insert devices and systems are commercially available or under development. Their types and names along with the prices and amount of water required and other information are listed on Table 6-1. For detailed description of these devices, see Appendix B.

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS

Type and Name	PRICE (in $)					WATER USED (in gpcd)						
	0-25	25-100	100-500	500-1000	1000+	0	0-2	2-10	10+	I	II	III#
A. INFILTRATION												
a. Pit latrine												
BICOQUE (France)	*					*						
CHIANG MAI SQUATTING PLATE (Thailand)	7.50						1.5					
b. Aqua privy												
FLUSH-O-MATIC (Canada)		80					1.5					opt
HEAD-MATE (U.S.A.)		100					1.5					
MARINE HAND TOILET (Canada)		75					1.5					
B. MANUAL REMOVAL												
a. Bucket												
PORTA POTTI (U.K.)		100					0.7					
b. Chemical toilet												
PERDISAN STANDARD MINOR (U.K.)		75				*					*	
RANCH (France)		*				*					*	

I = Power required, II = Chemical required, III = Water mains connected

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name		PRICE (in $) 0-25	25-100	100-500	500-1000	1000+	WATER USED (in gpcd) 0	0-2	2-10	10+	I	II	III*
IGLOO	(France)		*				*					*	
CLOSESSO PERFECTA	(France)		72				*					*	
MOBILCLOSET	(France)		72				*					*	
SANITAM STANDARD	(France)		50				*					*	
SANITAM SALUBRIS	(France)		33				*					*	
c. Freeze toilet													
MARKT	(Norway)			*			*				*		
ELSTAR	(Norway)			*			*				*		
MINIHJARTAT	(Sweden)			383			*				*		
TE-BE T-1970	(Sweden)			336			*				*		
d. Packing toilet													
PACTO 101	(Sweden)				621		*				*		
e. Recirculating chemical toilet													
JETFLUSH MINOR	(U.K.)			*			*				*	*	
MONOMATIC	(U.S.A.)			195				*			*	*	
POTPOURRI	(Canada)		70					1.5				*	
CRAFT TOILET	(U.S.A.)			215				*			*	*	

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name		PRICE (in $)					WATER USED (in gpcd)						
		0-25	25-100	100-500	500-1000	1000+	0	0-2	2-10	10+	I	II	III
C. MECHANICAL REMOVAL													
a. Vacuum truck													
OJO 7000	(Sweden)				550			1			*		
OJO 7100	(Sweden)			365				0.2					*
b. Chemical privy													
TURQUO	(France)			*					10			*	*
MANOIR	(France)			272					10			*	*
CASTEL	(France)			182				1.5				*	*
CAUSTICA 128	(France)		98					*				*	
CLOSENET STANDARD	(France)		50					2				*	
c. Recirculating fluid toilet													
MAGIC FLUSH	(U.S.A.)	N	A				*				*		
BIO-FLO 512	(U.S.A.)			329			*					*	
BIOCYCLE MK 1	(Ireland)			230				*				*	
d. Water-borne network													
SHALLOW TRAP (LOW TRAP)	(U.S.A.)		75							20			

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	PRICE (in $) 0-25	25-100	100-500	500-1000	1000+	WATER USED (in gpcd) 0	0-2	2-10	10+	I	II	III
BATCH TYPE FLUSH VALVES (2) IN DUAL CYCLE (U.S.A.)			145					8.5				
BATCH TYPE FLUSH VALVE (1) (U.S.A.)			98						16.5			
URINAL WITH BATCH-TYPE FLUSH VALVE (U.S.A.)	N	A							17			
DUAL CYCLE WATER CLOSET	N	A						6.5				
BRITISH TYPE (England)												
ECONO-FLUSH (U.S.A.)	14								20.7			
SINK-BOB (U.S.A.)	4								18.6			
SAVEIT WATER SAVER (U.S.A.)	6								18.6			
TOTO 5 (Japan)		*							18.8			*
MSU 2 (Canada)		50							18.8			*

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	PRICE (in $)					WATER USED (in gpcd)						
	0-25	25-100	100-500	500-1000	1000+	0	0-2	2-10	10+	I	II	III
NIBO (Uruguay)	*								17.5			*
BRICK-IN-THE-TANK (U.S.A.)	0.06							*				*
PEDAMATIC 2 (U.S.A.)		85					*					
DUAL FLUSH CISTERN (England)	17											*
e. Vacuum Network												
VACU-FLUSH (SINCLE HOME U.S.A.)				710			1			*		
VACUUM FLUSH (100 HOME Sweden)				524			1					
ELECTROLUX VACUUM SEWAGE SYSTEM (Sweden)					1177		*			*		
D. DESTRUCTION												
a. Incinerating Toilet												
DESTROILET (U.S.A.)			415			*				*		

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	PRICE (in $)					WATER USED (in gpcd)						
	0-25	25-100	100-500	500-1000	1000+	0	0-2	2-10	10+	I	II	III
ELONETTE (Sweden)			364			*				*		
TOARETT (Sweden)			325			*				*		
ECETT (Sweden)				781		*				*		
ELECTRO				847		*				*		
STANDARD (Sweden)												
E. DECOMPOSITION												
a. Compost privy												
CLIVUS (Sweden)				720		*						
MULL-TOA (Norway)			350			*				*		
SANITERM (Sweden)				742		*				*		
MULLBANK (Sweden)			308			*				*		
MULTRUM (Denmark)		*				*						
FARALLONES PRIVY (U.S.A.)		100				*						
KERN COMPOST PRIVY (U.S.A.)			*				*					

TABLE 6-1 PRICES AND WATER REQUIREMENTS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	PRICE (in $)					WATER USED (in gpcd)						
	0-25	25-100	100-500	500-1000	1000+	0	0-2	2-10	10+	I	II	III
b. Continuous aeration												
ECOL SANITARY			175			*				*		
UNIT (Canada)												
c. Algae Digester												
ECO-HOUSE (England)	N	A				*						
F. HOUSEHOLD WASTE TREATMENT												
PLANT												
WHO METHANE			*				*					
PLANT (Switzerland)												
MELANESIAN			300				*					
METHANE												
DIGESTER (New Guinea)												
FLO-THRU (U.S.A.)				1020			*			*		
CROMAGLASS			*			*	*					
C-5 (U.S.A.)												
BIO-DISC (Canada)				4300		*	*					
AQUAROBIC (Canada)				1850		*	*					

6.2 Faucet Flow Reduction Devices

Limiting flow valves and mixing valves that restrict the maximum flow rate have been commercially available or underdeveloped. These valves can be used not only for shower heads, but also in kitchen sinks and bathroom lavatories.

6.2.1 Flow Limiting Shower Heads

This type of shower head is a conventional shower head equipment with an integral "auto-flo" flow limiting orifice with a flow rate of 3.5 gpm or 2.5 gpm. It has a full-adjustable spray, integral ball joint and a face of about 2 inches diameter. Its standard 1/2 inch J.P.S. female inlet is compatible with standard shower arms. The quantity of water saved will depend on many factors such as water pressure, the habits of the user, etc. Generally speaking, there is 0.7 gpcd (or 50 to 70%) water saved when comparing with conventional shower head.

6.2.2 Flow Limiting Valves for Lavatory and Kitchen Sink

The design is the same as the previous one. The flow is usually restricted to 2.5 gpm for each valve. Water savings are claimed to be up to 50%

6.2.3 Faucet Aerator (for Lavatory and Kitchen Sink)

Although intended principally as an anti-splash device, it does provide some water savings. It is estimated that faucet aerator can reduce water consumption by approximately 25%

6.2.4 Thermostatic Mixing Valve (for Shower or Tub)

This is a device which permits mixing of hot and cold water to attain a desired temperature level. The proportion of hot and cold water is varied automatically by a bi-metallic coil as the temperature or pressure of the incoming water is varied. This device has the following advantages:

(1) Water saving: It enables the bather to turn the shower off while soaping and to have the same temperature when the water is turned on for rinsing. This saves the water that would be wasted as the water temperature is readjusted before rinsing or the water that would be wasted if the shower is left on in order to avoid the problem of adjusting the temperature again.

(2) Safety: The bather is not in danger of being suddenly scalded or doused with cold water as others in the household stop using or begin using water at other fixtures. This diminishes the danger of falls as bather is trying to avoid the sudden changes in water temperature while standing on slippery tub or shower floor.

Total cost and water savings of each of the above faucet flow reduction devices are shown on Table 6-2.

TABLE 6-2 TOTAL COSTS AND WATER SAVINGS OF FAUCET FLOW REDUCTION DEVICES

Type	Total Cost (in Dollars)	Water Used (in gpcd)	Water Saved (in gpcd)
A. Limiting flow valves for shower	30	6.0	6.0
B. Thermostatic mixing valve in tub and shower	50-100	18.0	2.0
C. Limiting flow valves for lavatory	30	1.5	0.5
D. Limiting flow valves for kitchen sink	30	6.25	0.5
E. Aerator faucet for lavatory and kitchen sink	3	8.25	0.5

6.3 Water Recycling Systems

6.3.1 Reuse of Wash Water for Toilet Flushing and Lawn Sprinkling

The reuse of wash waters for flushing toilets and lawn sprinkling is a scheme in which the water from the laundry and from bathing is collected and used as the flushing liquid in the water closet and as lawn sprinkling water, thus saving the amount of water normally used for toilet flushing and lawn sprinkling. The water for reuse for flushing toilets does not require high standards, because it is not to be ingested or to come in contact with the body. However, reuse for lawn sprinkling may present a possible hazard because of the greater accessibility to the recycled wash water, if any pathogen is present. This hazard can be eliminated by disinfection of the recycled wash water, and by a suitable underground discharge system.

The detergents from laundry operations should make the water safer from a health viewpoint, since many detergents are bacterial. The main treatment problem is to make the water aesthetically acceptable. Possible aesthetic parameters would be foaming, suspended solids, odor, and color. Suspended solids can be removed by filtration; if odor, foaming, and color are problems, the causative agents could be removed by activated carbon.

The physical requirements of the system are collection of waste waters, storage of this water until usage, and a means of supplying the water to the water closet for use. To collect the water, existing drains must be rerouted or replaced, and tank provided for storage. The pump is used to lift the water to the water closet from abrasive solids. Also, a pressure tank is required to supply pressurized water to the water closet and lawn sprinkler.

A filtration system is incorporated into the wash water recycle system in order to remove suspended solids that might affect operation of the pressurization system, and to provide an effluent of sufficient clarity. In the search for an optimum filtration system, the desired degree of filtration must be tempered by consideration of economic feasibility and convenience to the home owner.

Two types of filters are found to be able to meet these requirements: diatomic filter and cartridge filter. The diatomite filter can achieve the better performance, while the cartridge filter is more economical. But a substantial cost reduction can be expected for a mass produced, cost optimized version of the diatomite type recycle system.

6.3.2 Reuse of Wash Water for Toilet Flushing Only

This system is the same as the previous one except that the recycled water is used for toilet flushing only, and is not disinfected.

6.3.3 Distillation of Wastes with Reuse for All but Drinking and Cooking

Available distillation devices cannot handle solid materials effectively without excessive scaling. The most inexpensive method of removing and treating the solids would be by sedimentation and filtration. These could be supplied by a septic tank and a commercially available pressurized sand filter. This clarified liquid would then be fed to the distillation apparatus. If a vapor compression device such as the Hickman still is used, 85% of the feed water will be recoverable in the distillation process without significantly increasing operating costs. The low temperature operation of this still would prevent the volatilization of many organic materials, but the product water would still require disinfection and carbon absorption treatment to make the effluent acceptable for health and aesthetic standards.

6.3.4 Reuse of Non-Sanitary Wastes for Toilet Flushing after Filtration, and for Laundry after Distillation

This is merely an alternate combination of devices described in the previous sections. The wash water is reused for toilet flushing after filtration, and for laundry after distillation.

Information on the water savings and total costs of all the water recycling systems are tabulated in Table 6-3.

6.4 Other Water Conservation Appliances

6.4.1 Washing Machine with Water Level Control

It has a loading door which acts as a weighing scale to measure the amount of clothes to be washed. Knowing the weight of the clothes, the user then selects only the amount of water required to wash the particular load size.

6.4.2 Front Loader Washer

The washer tub rotates on a horizontal axis and tumbles the clothes through the water. It uses approximately half as much water as compared to the top loading washers.

TABLE 6-3 TOTAL COSTS AND WATER SAVINGS OF WATER RECYCLING SYSTEMS

Type	Total Cost (in Dollars)	Water used in addition to the recycled water (in gpcd)	water saved (in gpcd)
A. Reuse of wash water for toilet flushing and Lawn sprinkling			
a. Prototype (with diatomite filter)	640	30.0	11.6
b. Prototype (with cartridge filter)	540	30.0	11.6
c. Mass Produced	400	30.0	11.6
B. Reuse of wash water for toilet flushing only	not available	0	24.0
C. Distillation of wastes with reuse for all but drinking & cooking	2760	2.0	55.0
D. Reuse of non-sanitary wastes for toilet flushing after filtration, and for laundry after distillation	1720	23.75	10.0

CHAPTER VII

THE EFFECT OF ENERGY SAVINGS THROUGH VARIOUS ALTERNATIVES

7.1 Scope

The primary goal of this study is to evaluate energy saved by using various water conservation devices. This chapter contains the tabulated results of cost-effectiveness analysis of the different energy savings.

Energy savings or expenditures through water conservation practices include all direct and indirect energy consumption. For example, the manufacturing of materials for new installations or for replacements of defective existing hardware, the production of chemicals, and the saving of not constructing additional water and sewage facilities all are involved with the expenditure of energy. In addition, labor required is also an incalculable energy consumption. Factually, it is unlikely to list down all possible energy expenditures, let alone the analysis of cost-effectiveness on the various alternatives of energy savings by water conservation practices.

In this study, four areas of immediate savings in energy are dealt with numerically:

A) Energy (electricity or fuel) saving on expenditure through inlet water reduction process

B) Energy (for water heating) saving or expenditure through hot-water reduction

C) Energy saving or expenditure of wastewater operation through wastewater reduction

D) Energy saving or expenditure of water production operation through domestic water reduction

All the energy units mentioned above are converted by the use of latest price rates into monetary values, or commensurate terms for more appropriate comparison. Information needed for determination are listed in Chapter III, IV and V. Section 7.2 and 7.3 include a step-wise explanation of the cost effectiveness analysis.

7.2 Cost-effectiveness Analysis

Cost-effectiveness analysis (17) as applied in this study, is defined as an analytic study designed to assist a decision-maker in identifying a preferred choice among possible water conservation alternatives. It involves a two steps evaluation procedure. The first is cost evaluation which entails the delineation of all major water reduction systems and the development of water and energy saving value for each. The second is the effectiveness evaluation in which one attempts to generate a single basic measure or indicator of effectiveness using multiple considerations. The essence of cost-effectiveness analysis then compares the trade-off of cost with effectiveness to identify the most cost effective alternative.

In this cost-effectiveness analysis, the comparative total energy-savings are measured in accord to the four energy expenditures described in Section 7.1. The total savings in water simply come from the product of the amount of water saved and the current rate of domestic water usage. The highest final saving based on the offset of energy and water saving is considered most cost-effective or practicable.

An example on the next page evaluates the cost-effectiveness of a vacuum flush toilet for single home. With the installation of a vacuum

Example of Cost-effectiveness Analysis

i) Assumptions: (Based on the facts shown in previous chapters)

ITEM	ASSUMPTION
Water usage of conventional water-borne toilet	24 gpcd
Water rate (domestic, over 2,000 Kgal/month)	90¢/Kgal
Hot-water rate	67¢/Kgal
Energy rate: electricity	3.25¢/KWH
liquefied petroleum gas	7.5¢/lb
natural gas	150¢/MCF
Energy cost in wastewater treatment plant	0.79¢/Kgal wastewater
Energy cost in water production plant	1.81¢/Kgal

ii) Cost-effectiveness: (in the unit of $/home/yr)

	Vacuum flush toilet (for single home)	Conventional water-borne toilet
(Water used)	(1.5 gpcd)	(24 gpcd)
Energy cost:		
thru'process	$21.76	-
thru'water heating	-	-
thru' wastewater trmt.	$0.02	$0.28
thru' water production	$0.04	$0.63
Total energy cost	$21.82	$0.91
Water cost (domestic)	$ 1.97	$31.54
Final Cost	$23.79	$32.45
Overall Saving	$8.66	

flush toilet in place of a conventional water-borne toilet, the total annual energy expenditure can increase from $.91 to $21.82, showing an additional expense of $20.19. However, in doing this, the total annual water bill will reduce from $31.54 to $1.97, a total saving of $29.57. In this situation, the overall result is an annual saving of $8.66. This example indicated that from an energy conservation view point, it may be cost-effective to use vacuum flush toilets for single homes. But, if things like amortized capital cost, maintenance cost, treatment cost, etc. are considered, the effectiveness may become different.

Similar determinations of total savings of energy and water of all the devices (described in Table 6-1 to 6-4)are compiled in Table 7-1, 7-2, 7-3 and 7-4. The many assumptions that were made in each choice of device, like size of the motor, average operating time, etc. are also attached at the end of the description of each device in Chapter VI and Appendix B.

7.3 Rating for Various Water Conservation Alternatives

In studying Column VIII and IX of Table 7-1, i.e. total energy saving and total water saving respectively, one may discover among the 68 water conservation alternatives only 16 were given a different notation. This indicates that these 16 devices or systems are more energy demanding than the conventionally installed ones. These are actually the alternatives that consume additional energies of column IV and V, other than Column VI and VII and thus warranted careful study. Under normal situations, the other alternatives are obviously both water-saving and energy-saving, and thus are unnecessary of further analysis and weighting. For this reason, the rating of the overall savings will only be on these "problem" alternatives.

According to the asterisked overall savings presented on the Column X of Table 7-1, 7-2, 7-3 and 7-4, the order of desirability of the problem water conservation alternatives is shown in Table 7-5 and 7-6, followed by the final cost-effectiveness value in terms of dollar value.

COLUMN NOTATION (AND UNITS) FOR TABLE 7-1, 7-2, 7-3 AND 7-4

I: Water saved (gpcd)

II: Percentage of water saved in conventional units modified (%)

III. Percentage of water saved with respect to domestic water usage (%)

IV: Savings (+ or -) in energy by various water conservation alternatives ($/home/yr)

V: Savings (+ or -) in energy by reduction of hot water usage ($/home/yr)

VI: Savings (+ or -) in energy for waste treatment by wastewater reduction ($/home/yr)

VII: Savings (+ or -) in energy for water supply treatment by domestic use reduction ($/home/yr)

VIII: Total savings in energy ($/home/yr)

IX: Total savings in water ($/home/yr)

X: Overall savings ($/home/yr)

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS

Type and Name		I	II	III	IV	V	VI	VII	VIII	IX	X
A. INFILTRATION											
a. Pit latrine											
BICOQUE	(France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
CHIANG MAI SQUATTING PLATE	(Thailand)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
b. Aqua privy											
FLUSH-O-MATIC	(Canada)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
HEAD-MATE	(U.S.A.)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
MARINE HAND TOILET	(Canada)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
B. MANUAL REMOVAL											
a. Bucket											
PORTA POTTI	(U.K.)	23.3	97.2%	38.0%	-	-	+0.27	+0.62	+0.89	+30.62	+31.51
b. Chemical toilet											
PERDISAN STANDARD MINOR	(U.K.)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
RANCH	(France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	I	II	III	IV	V	VI	VII	VIII	IX	X
IGLOO (France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
CLOSESSO PERFECTA (France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
MOBILCLOSET (France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
SANITAM STANDARD (France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
SANITAM SALUBRIS (France)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
c. Freeze toilet										
MARKT (Norway)	24.0	100%	39.1%	-8.54	-	+0.28	+0.63	+0.91	+31.54	+32.45
ELSTAR (Norway)	24.0	100%	39.1%	-9.25	-	+0.28	+0.63	+0.91	+31.54	+32.45
MINIHJARTAT (Sweden)	24.0	100%	39.1%	-10.67	-	+0.28	+0.63	+0.91	+31.54	+32.45
TE-BE T-1970 (Sweden)	24.0	100%	39.1%	-8.54	-	+0.28	+0.63	+0.91	+31.54	+32.45
d. Packing toilet										
PACTO 101 (Sweden)	24.0	100%	39.1%	-0.16	-	+0.28	+0.63	+0.91	+31.54	+32.45
e. Recirculating chemical toilet										
JETFLUSH MINOR (U.K.)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
MONOMATIC (U.S.A.)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75
POTPOURRI (Canada)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
CRAFT TOILET (U.S.A.)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name		I	II	III	IV	V	VI	VII	VIII	IX	X
C. MECHANICAL REMOVAL											
a. Vacuum truck											
OJO 7000	(Sweden)	23.0	95.9%	37.5%	-0.7	-	+0.27	+0.61	+0.11	+30.22	+30.33
OJO 7100	(Sweden)	23.8	99.3%	38.8%	-	-	+0.28	+0.63	+0.91	+31.27	+32.18
b. Chemical privy											
TURQUO	(France)	14.0	58.4%	22.8%	-	-	+0.16	+0.37	+0.53	+18.40	+18.93
MANOIR	(France)	14.0	58.4%	22.8%	-	-	+0.16	+0.37	+0.53	+18.40	+18.93
CASTEL	(France)	22.5	93.8%	36.7%	-	-	+0.26	+0.59	+0.85	+29.57	+30.42
CAUSTICA 128	(France)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75
CLOSENET STANDARD	(France)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75
c. Recirculating fluid toilet											
MAGIC FLUSH	(U.S.A.)	24.0	100%	39.1%	NA	-	+0.28	+0.63	+0.91	+31.54	+32.45
BIO-FLO 512	(U.S.A.)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
BIOCYCLE MK 1	(Ireland)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	I	II	III	IV	V	VI	VII	VIII	IX	X
d. Water-borne network										
SHALLOW TRAP (LOW TRAP)										
(U.S.A.)	3.9	16.3%	6.4%	–	–	+0.05	+0.10	+0.15	+5.12	+5.27
BATCH-TYPE FLUSH VALVES (2) IN DUAL CYCLE										
(U.S.A.)	15.5	64.6%	25.3%	–	–	+0.18	+0.41	+0.59	+20.38	+20.97
BATCH TYPE FLUSH VALVE (1)										
(U.S.A.)	7.5	31.3%	12.2%	–	–	+0.09	+0.20	+0.29	+9.86	+10.15
URINAL WITH BATCH-TYPE FLUSH VALVE										
(U.S.A.)	7.0	29.2%	11.4%	–	–	+0.08	+0.18	+0.26	+9.20	+9.46
DUAL CYCLE WATER CLOSET										
BRITISH TYPE (England)	17.5	73.0%	28.5%	–	–	+0.20	+0.46	+0.66	+23.00	+23.66
ECONO-FLUSH (U.S.A.)	3.3	13.8%	5.4%	–	–	+0.04	+0.09	+0.13	+4.34	+4.47
SINK-BOB (U.S.A.)	5.4	22.5%	8.8%	–	–	+0.06	+0.14	+0.20	+7.10	+7.30
SAVEIT WATER SAVER										
(U.S.A.)	5.4	22.5%	8.8%	–	–	+0.06	+0.14	+0.20	+7.10	+7.30
TOTO 5 (Japan)	6.0	25%	9.8%	–	–	+0.07	+0.16	+0.23	+7.88	+8.11
MSU 2 (Canada)	6.0	25%	9.8%	–	–	+0.07	+0.16	+0.23	+7.88	+8.11

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name	I	II	III	IV	V	VI	VII	VIII	IX	X
NIBO (Uruguay)	7.5	31.13	12.2%	-	-	+0.9	+2.0	+0.29	+9.86	+10.15
BRICK-IN-THE-TANK										
(U.S.A.)	14.0	58.4%	22.8%	-	-	+0.16	+0.37	+0.53	+18.40	+18.93
PEDAMATIC 2 (U.S.A.)	21.0	87.6%	34.2%	-	-	+0.24	+0.55	+0.79	+27.60	+28.39
VACU-FLUSH										
e. Vacuum Network										
VACU-FLUSH										
(SINGLE HOME U.S.A.)	22.5	93.8%	36.2%	-21.76	-	+0.26	+0.59	-20.91	+29.57	+ 8.66*
VACUUM FLUSH										
(100 HOME Sweden)	22.5	93.8%	36.2%	- 4.76	-	+0.26	+0.59	- 3.91	+29.57	+25.66*
ELECTROLUX VACUUM										
SEWAGE										
SYSTEM (Sweden)	22.0	91.7%	35.9%	-21.76	-	+0.26	+0.58	-20.92	+28.91	+7.99*
D. DESTRUCTION										
a. Incinerating										
Toilet										
DESTROILET (U.S.A.)	24.0	100%	31.9%	-29.87	-	+0.28	+0.63	-28.96	+31.54	+2.58*

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name		I	II	III	IV	V	VI	VII	VIII	IX	X
ELONETTE	(Sweden)	24.0	100%	39.1%	-58.4	-	+0.28	+0.63	-57.49	+31.54	-25.95*
TOARETT	(Sweden)	24.0	100%	39.1%	-116.8	-	+0.28	+0.63	-115.89	+31.54	-84.35*
ECETT	(Sweden)	24.0	100%	39.1%	-87.6	-	+0.28	+0.63	-86.69	+31.54	-55.15*
ELECTRO STANDARD	(Sweden)	24.0	100%	39.1%	-73.0	-	+0.28	+0.63	-72.09	+31.54	-40.55*
E. DECOMPOSITION											
a. Compost privy											
CLIVUS	(Sweden)	24.0	100%	39.1%	-	-	+0.28	+0.63	+ 0.91	+31.54	+32.45
MULL-TOA	(Norway)	24.0	100%	39.1%	-15.77	-	+0.28	+0.63	-14.86	+31.54	+16.68*
SANITERM	(Sweden)	24.0	100%	39.1%	-87.60	-	+0.28	+0.63	-86.69	+31.54	-55.15*
MULLBANK	(Sweden)	24.0	100%	39.1%	-21.90	-	+0.28	+0.63	-20.99	+31.54	+10.55*
MULTRUM	(Denmark)	24.0	100%	39.1%	-	-	+0.28	+0.63	+ 0.91	+31.54	+32.45
FARALLONES PRIVY	(U.S.A.)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
KERN COMPOST PRIVY	(U.S.A.)	22.0	91.7%	35.9%	-	-	+0.26	+0.58	+0.84	+28.91	+29.75

TABLE 7-1 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS (Continued)

Type and Name		I	II	III	IV	V	VI	VII	VIII	IX	X
b. Continuous aeration											
ECOL SANITARY											
UNIT	(Canada)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
c. Algae Digester											
ECO-HOUSE	(England)	24.0	100%	39.1%	-	-	+0.28	+0.63	+0.91	+31.54	+32.45
F. HOUSEHOLD WASTE TREATMENT											
PLANT											
WHO METHANE											
PLANT	(Switzerland)	22.0	91.7%	35.9%	+1.16	-	+0.26	+0.58	-0.32	+28.91	+28.59*
MELANESIAN											
METHANE											
DIGESTER	(New Guinea)	22.0	91.7%	35.9%	+193.20	-	+0.26	+0.58	+194.04	+28.91	+222.95
FLO-THRU	(U.S.A.)	22.0	91.7%	35.9%	- 53.08	-	+0.26	+0.58	- 52.24	+28.91	- 23.33*
CROMAGLASS											
C-5	(U.S.A.)	4.0	16.7%	6.5%	- 53.08	-	+0.05	+0.11	-52.92	+ 5.26	- 47.66
BIO-DISC	(Canada)	4.0	16.7%	6.5%	- 0.95	-	+0.05	+0.11	- 0.79	+ 5.26	+ 4.47*
AQUAROBIC	(Canada)	4.0	16.7%	6.5%	-53.08	-	+0.05	+0.11	-52.92	+5.26	-47.66*

*These overall savings of the corresponding "problem" alternatives are to be rated in Table 7-5.

TABLE 7-2 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER CONSERVATION SHOWERHEAD, VALVE AND FAUCET INSERT DEVICES

Type	I	II	III	IV	V	VI	VII	VIII	IX	X
A. Limiting flow valves for shower	6.0	50%	9.8%	-	+3.82	+0.07	+0.16	+4.05	+7.88	+11.93
B. Thermostatic mixing valve in tub and shower	2.0	10%	3.3%	-	+1.27	+0.02	+0.05	+1.34	+2.63	+3.97
C. Limiting flow valves for lavatory	0.5	25%	0.8%	-	+0.32	+0.01	+0.01	+0.34	+0.66	+1.00
D. Limiting flow valves for kitchen sink	0.5	7.4%	0.8%	-	+0.32	+0.01	+0.01	+0.34	+0.66	+1.00
E. Aerator faucet for lavatory and kitchen sink	0.5	5.7%	0.8%	-	+0.32	+0.01	+0.01	+0.34	+0.66	+1.00

TABLE 7-3 SAVINGS IN WATER AND ENERGY AS A RESULT OF WATER RECYCLE SYSTEMS

Type	I	II	III	IV	V	VI	VII	VIII	IX	X
A. Reuse of wash water for toilet flushing and Lawn sprinkling										
a. Prototype (with diatomite filter)	11.6	26.0%	18.9%	-12.00	-	+0.13	+0.31	-11.56	+15.24	+3.68*
b. Prototype (with cartridge filter)	11.6	26.0%	18.9%	- 1.20	-	+0.13	+0.31	- 0.76	+15.24	+14.48*
c. Mass Produced	11.6	26.0%	18.9%	- 7.00	-	+0.13	+0.31	-6.56	+15.24	+ 8.68*
B. Reuse of wash water for toilet flushing only	24.0	100.0%	39.0%	- 3.65	-	+0.29	+0.63	-2.73	+13.27	+10.54
C. Distillation of wastes with reuse for all but drinking & cooking	55.0	96.5%	89.7%	-182.00	-	+0.64	+1.45	-179.27	+72.27	-107.64*
D. Reuse of non-sanitary wastes for toilet flushing after filtration, and for laundry after distillation	10.0	29.6%	16.3%	-34.00	-	+0.12	+0.26	- 33.62	+13.14	- 20.48*

*These overall savings of the corresponding "problem" alternatives are to be rated in Table 7-6.

TABLE 7-4 SAVINGS IN WATER AND ENERGY AS A RESULT OF OTHER WATER CONSERVATION APPLIANCES

Type	I	II	III	IV	V	VI	VII	VIII	IX	X
A. Automatic clothes Washer	1.2	13.7%	2.0%	-	+0.59	+0.01	+0.03	+0.63	+1.58	+2.21
B. Front Loader Washer	4.4	50.0%	7.2%	-	+2.15	+0.05	+0.12	+2.32	+5.78	+8.10

TABLE 7-5 RATING FOR WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS

Order of rating	Name of the device or system	Overall saving ($/home/yr)
1	F. WHO METHANE PLANT	+28.59
2	C-e. VACUUM FLUSH (100 HOMES)	+25.66
3	E-a. MULL-TOA	+16.68
4	E-a. MULLBANK	+10.55
5	C-e. VACUUM FLUSH (SINGLE HOME)	+ 8.66
6	C-e. ELECTROLUX VACUUM SEWAGE SYSTEM	+ 7.99
7	F. BIO-DISC	+ 4.47
8	D-a. DESTROILET	+ 2.58
9	F. FLO-THRU	-23.33
10	D-a. ELONETTE	-25.95
11	D-a. ELECTRO STANDARD	-40.55
12	F. CROMAGLASS C-5	-47.66
	F. AQUAROBIC	-47.66
13	D-a. ECETT	-55.15
	E-a. SANITERM	-55.15
14	D-a. TOARETT	-84.35

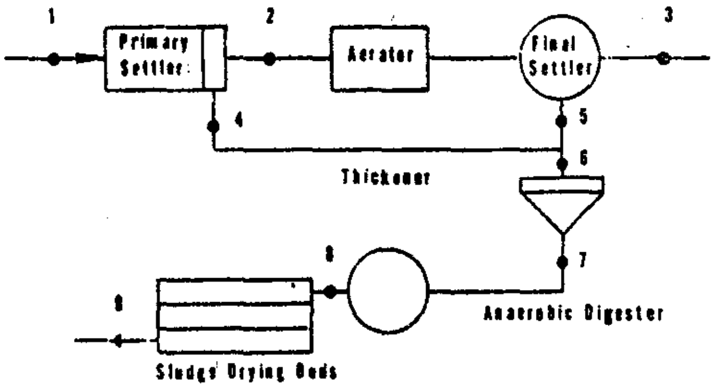
TABLE 7-6 RATING FOR WATER RECYCLE SYSTEMS

Order of rating	Type of System	Overall savings ($/home/yr)
1	A-b. Prototype (with catridge filter)	+14.48
2	B. Reuse of wash water for toilet flushing only	+10.54
3	A-c. Mass produced	+ 8.68
4	A-a. Prototype (with diatomite filter)	+3.68
5	D. Reuse of non-sanitary wastes for toilet flushing after filtration, and for laundry after distillation	-20.48
6	C. Distillation of wastes with reuse for all but drinking & cooking	-107.64

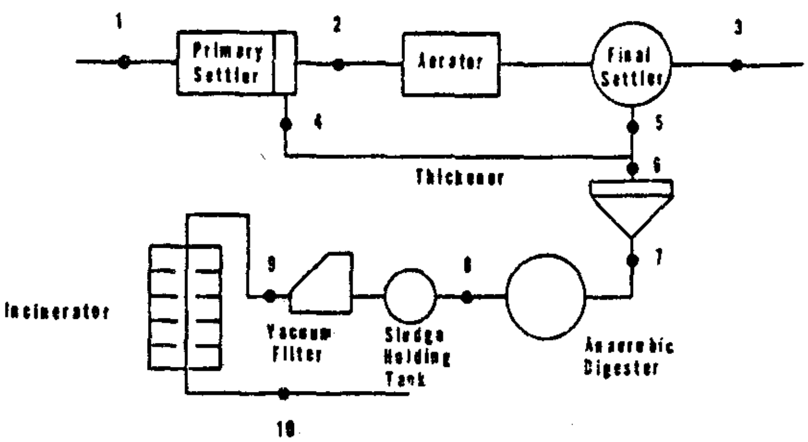
APPENDIX

APPENDIX A

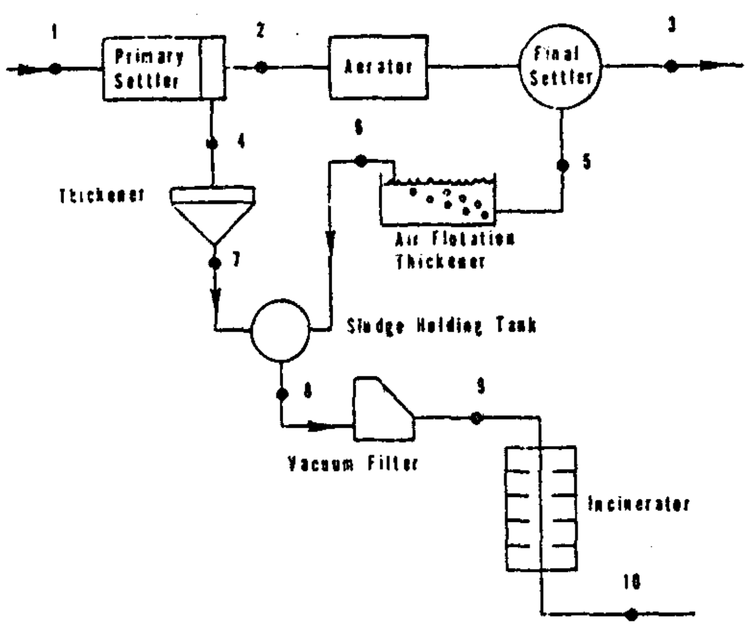
SELECTED SLUDGE HANDLING SCHEMES FOR WASTEWATER TREATMENT PLANTS*



SLUDGE HANDLING SCHEME I



SLUDGE HANDLING SCHEME II



SLUDGE HANDLING SCHEME III

*Source: "Electrical Power Consumption for Municipal Wastewater Treatment", EPA-R2-73-281, 1973

APPENDIX B

DETAILED DESCRIPTIONS OF WATER CONSERVATION TOILET INSERT DEVICES AND SYSTEMS

ITEM		ASSUMPTION
Water use of the average family		See Table 3-3
Occupants in the average family		4 (2 adults & 2 children)
Average visit of toilet room per person per day		5 times
Water rate (domestic, over 2,000 Kgal/month)		90.00 ¢/Kgal
Hot-water rate		67.00 ¢/Kgal
Energy rate:	electricity	3.25¢/KWH
	liquefied petroleum gas	7.50¢/lb
	nature gas	150.00¢/MCF
Energy cost in wastewater treatment plant		0.79¢/Kgal wastewater
Energy cost in water production plant		1.81¢/Kgal

BICOQUE | A. INFILTRATION

Cost: Under $25.00 | a. Pit latrine

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e, France

This is simply a toilet-seat for a pit latrine which incorporates a trap-door type device for keeping odors from escaping the pit. It is made out of heat-formed plastic.

CHIANG MAI SQUATTING PLATE | A. INFILTRATION

Cost: $7.50 | a. Pit latrine

Mold available from:
Village Health & Sanitation Project
Ministry of Public Health, Bangkok, Thailand

This is an aluminum master-mold used for casting a low-cost, water-sealed, squatting-plate, which would be produced in a village situation and would be used over a pit, or aqua privy. Each time the toilet is used, a quart (1.1 litres) is poured to flush the waste and maintain the water seal.

This excellent design has been developed for use with a pasty cement/water mix. The Minimum Cost Housing Group has successfully cast sulphur-concrete squatting plates with this mold, thus giving a non-porous, easy to maintain toilet.

FLUSH-O-MATIC | A. INFILTRATION

Cost: $79.05 (toilet alone) or $175.50 (including tank) | b. Aqua privy

Manufactured by:
Sanitation Equipment Limited
Rexdale, Ontario, Canada

This system includes a toilet and a steel holding tank. Total weight is 175 pounds (79 kg). A foot-operated valve flushes 1 quart (1.1 litres) of water, which may be from a cistern, directly from water mains, or poured manually into the bowl. This unit uses little water, is mechanically simple and has the advantage of being able to function when there is no water in the reservoir by pouring directly into the toilet.

HEAD-MATE — A. INFILTRATION, b. Aqua privy

Cost: $106.50

Manufactured by:
Wilcox-Crittenden Seaclos
Connecticut, USA.

This is a marine toilet which is designed to function on small amounts of water. It would most normally be connected as an aqua privy, or in the case of a boat, to a holding tank. Water is hand pumped to clean bowl and flush toilet. About 6 strokes of the pump are necessary to pump the quart (1.1 litres) of water needed for flushing. The bowl is of vitreous china and non-corrosive metals. The unit weighs 20 pounds (9kg). The same company makes an electrically powered model for $259.00.

MARINE HAND TOILET — A. INFILTRATION, b. Aqua privy

Cost: $75.00

Manufactured by:
International Telephone & Telegraph
Rexdale, Ontario, Canada

A marine toilet in which water is manually pumped to clean and flush the toilet. The unit is of vitreous china and stainless steel and bronze and weighs 23 pounds (10.4 kg). This kind of toilet might find application in areas where water is scarce and electric power not available for maintaining waterpressure. The inlet could be attached to a rain-water barrel for instance. Amount of water per flushing is 1 quart (1.1 litres).

PORTA POTTI — A. MANUAL REMOVAL, a. Bucket

Cost: $105.00

Manufactured by:
Thetford Products Ltd.
Nuneaton, Worcester, England

This is a plastic portable toilet that consists of a 2.75 gallon (12.4 litre) water tank that flushes a pint (0.5 litres) of water each time into a holding tank that requires emptying after 50 uses. The holding tank detaches from the bowl. A deodorant chemical (not lye) is used in the holding tank. The flush pump is hand-operated.

PERDISAN STANDARD MINOR — B. MANUAL REMOVAL

Cost: $75.24 — b. Chemical toilet

Manufactured by:
Racasan Limited
Cromwell Road, Ellesmere Port, Wirral,
Cheshire L65 4DP, England

This portable bucket-style chemical toilet is of high-density polyethylene and weighs 17 pounds (7.7 kg). It is charged with a small amount of water and chemical. No water is used for flushing and the capacity is about 120 uses. After use the handle is depressed, which opens a spring loaded flop and lets the waste fall into the chemical solution. Special paper must be used. The unit can be permanently installed.

RANCH — B. MANUAL REMOVAL

Cost: Unknown — b. Chemical toilet

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e, France

This is a portable chemical toilet which is carried to the point of discharge and emptied. It can also be connected to a drain pipe for permanent fixing. A performed, chemical is added once a month to inhibit decomposition. No water is added. A handle opens the splash pan and moves a paddle within the reservoir. The unit is out of polyester plastic and stainless steel parts.

IGLOO — B. MANUAL REMOVAL

Cost: Unknown — b. Chemical toilet

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e, France

This is a portable bucket toilet to which chemicals are added, but no water. The removable bucket is inside a container. The bowl has a trapdoor device for keeping odours in.

CLOSESSO PERFECTA — B. MANUAL REMOVAL

Cost: $72.00 — b. Chemical toilet

Manufactured by:
Etablissements Goby
18 Rue Bascout, 94600 Choisy-le-Roi, France

This is an essentially fixed toilet which consists of an outer container with a removable bucket inside, all out of plastic. The bucket of 3 gallons (13.5 litres) capacity is removed to be emptied. A splash-pan protects the user.

MOBILCLOSET — B. MANUAL REMOVAL

Cost: $72.00 — b. Chemical toilet

Manufactured by:
Etablissements Goby
18 Rue Bascout, 94600 Choisy-le-Roi, France

This is a portable toilet with a capacity of 6 gallons (27 litres). The entire unit, weighing 11 pounds (5 kg) and is carried to the disposal area. One valve opens the outlet at the bottom of the unit. The other value operates the splash-pan. The unit is of plastic.

SANITAM STANDARD — B. MANUAL REMOVAL

Cost: $48.60 — b. Chemical toilet

Manufactured by:
Tehcniques Agricoles Modernes
1, Rue du Bac, Paris - 7, France

This toilet consists of an outer container and an inner removeable bucket, weighing 11 pounds (5kg), all out of plastic. An initial charge consists of 2 quarts (2 litres) of water and chemicals. The capacity of the bucket is 6 gallons (27 litres), though in practice it would be emptied when half-full, that is, for three people, once a week.

SANITAM SALUBRIS — B. MANUAL REMOVAL

Cost: $32.60 — b. Chemical toilet

Manufactured by:
Tehcniques Agricoles Modernes
1, Rue du Bac, Paris - 7, France

This is really a bucket toilet to which chemicals are added. When full the toilet is simply dumped out. The unit is of plastic and weighs 4.4 pounds (2 kg). It requires an initial change of 2 quarts (2 liters) and has a capacity of 6 gallons (27 litres).

MARKT

B. MANUAL REMOVAL

Cost: Unknown

c. Freeze toilet

Manufactured by:
Markt & Co. A/S
Kirkegt. 6B, Oslo 1, Norway

This toilet functions on the principle of a deep freeze. The waste falls into disposable paper bags (capacity 5 gallons, 22.5 litres) that are located beneath the seat. The disposable bag is located within a plastic bag for convenience. A 120 watt compressor (current 220 volt, 10 amps maintains the contents of the sack at +5°F (-15°C). Temperature is controlled by a thermostat. The waste is frozen solid, like a block of ice, so there is no smell, and bacterial action stops. No water is used. When the bag is 2/3 full it is removed and sealed. Since the bags a biodegradable and no chemicals are used, they can be composted to give garden fertilizer. The body of the unit is of fibreglass, and the inner refrigerator-container is aluminum. Weight is 77 pounds (35 kg). A practical note: warm air, from the compressor, is streamed over the seat to keep it warm.

Assumption: Percentage running time of the compressor (25%)

Saving in Energy: -120 W/home x 24 hr/d x 25% x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$8.54/home/yr

ELSTAR

B. MANUAL REMOVAL

Cost: Unknown

c. Freeze toilet

Manufactured by:
A.S. Elektrokjop
Okernsentret, Oslo 5, Norway

This toilet uses a 130 watt electrically-powered compressor which freezes the waste to +5°F (-15°C). The 5 gallon (22.5 litres) disposable bag will accomodate an average family for 10-14 days. The toilet requires a space 16" x 24" (40 x 60 cm), and is made of stainless steel. The seat is warmed by hot air. The manufacturer suggests three methods of disposal: (1) Bury bag, in which case everything decomposes, (2) Composting and (3) Removal to treatment plant.

Assumption: Percentage running time of the compressor (25%)

Saving in Energy: - 130 W/home x 24 hr/d x 25% x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$9.25/home/yr

MINIHJARTAT — B. MANUAL REMOVAL

Cost: $383.00 (including sales tax) — c. Freeze toilet

Manufactured by:
Osby-Pannan AB
285 00 Osby, Sweden

This toilet operates on 220 v, and is rated at <u>150 watts</u>. The capacity of the plastic bag is 9 gallons (40.5 litres). In case of a power-failure the contents will begin to smell after 24 hours and would have to be removed. Electrical cost is 3 cents per day (Sweden).

Assumption: Percentage running time of the compressor (25%)

Saving in Energy: -150 W/home x 24 hr/d x 25% x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$10.67/home/yr

TE-BE T-1970 — B. MANUAL REMOVAL

Cost: $336.00 (including sales tax) — c. Freeze toilet

Manufactured by:
Te-Be Elprodukter
Fack 34, 561 01 Huskvarna, Sweden

This toilet operates on 220 v, and is rated at <u>120 watts</u>. The capacity of the plastic bag is 6.6 gallons (29.7 litres). Electrical cost is 3 cents per day (Sweden).

Assumption: Percentage running time of the compressor (25%)

Saving in Energy: -120 W/home x 24 hr/d x 25% x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$8.54/home/yr

PACTO 101 — B. MANUAL REMOVAL

Cost: $621.00 (incl. sales tax) — d. Packing toilet

Manufactured by:
Pactosan A/B
Box 100, 713 00 Nora Stad, Sweden

This is really a sophisticated bucket toilet. The waste is collected in a plastic tube and is sealed after each use. The "sausages" fall into a removable plastic bag. The sealing of the plastic is by heat (200 v. simple phase) and the movement of the plastic is accomplished by a foot-operated pedal. A meter clocks the number of uses, and a warning light prevents use of toilet if plastic runs out. The unit, of polystyrene and metal, is portable and of particularly rugged design, as it is sold for building construction sites.

Assumption: motor size (40W); operating time (1 min/visit)

Saving in Energy: -40 W/p x 4 p/home x 1 min/visit x 1/60 hr/min x 5 visit/d x 365 d/yr x $0.0325/KWH
= -$0.16/home/yr

JETFLUSH MINOR

B. MANUAL REMOVAL

e. Recirculating chemical toilet

Cost: Unknown

Manufactured by:
Racasan Limited
Cromwell Road, Ellesmere Port, Wirral
Cheshire L65 4DP, England

This is a portable toilet which weighs 18 pounds (8.2 kg) and is carried like a bucket. The waste falls into a chemical solution when a handle-operated flap is opened. Then the toilet bowl is cleaned by a perfumed sterilant, which is drawn back into the flushing bottle for re-use. The water pump operates from a 12 volt dry cell or car battery. The capacity is 100-120 average uses.

MONOMATIC

B. MANUAL REMOVAL

e. Recirculating chemical toilet

Cost: about $195.00

Manufactured by:
Monogram Industries Inc.
10131 National Blvd., L.A., California 90034, U.S.A.

This toilet is charged with 4 gallons (18 litres) of water and a chemical, which accomodates 100 uses before being replaced. The unit, originally developed for passenger airlines, uses a 12 v. electric motor to recirculate the fluid. It is mainly used in recreational vehicles. The unit is made out of plastic and weighs 35 pounds (15.75 kg) empty, and about 85 pounds (38.25 kg) when full.

POTPOURRI

B. MANUAL REMOVAL

e. Recirculating chemical toilet

Cost: about $69.95

Manufactured by:
Sanitation Equipment Limited
Rexdale, Ontario, Canada

This portable chemical toilet is made out of polyethylene and weighs 11 pounds (4.95 kg). The initial charge of water allows, with added chemicals to inhibit decomposition and smell, up to fifty re-uses before the reservoir

(6 gallons, 27 litres) must be emptied. Each flushing uses 1 quart (1.13 litres) of water. A manually operated handle opens the sealing trap and at the same time pumps water from the reservoir into the bowl. The pump contains a filter cartridge. The unit may be connected to a permanent water supply and used as a fixed toilet.

CRAFT TOILET

B. MANUAL REMOVAL

e. Recirculating chemical toilet

Cost: $215.00

Manufactured by:
Craft New York City, N.Y., U.S.A.

This essentially fixed toilet is made out of fibreglas and weighs 40 pounds (18 kg). The 7 gallon (31.5 litres) capacity tank is initially changed with 3 gallons (13.5 litres) of water together with chemicals. An electric - motor powers a pump that re-circulates this fluid for flushing; and electrically powered macrator breaks down all solids into liquids. The unit can be used about 200 times before it needs to be emptied. Electricity is 12 v.

OJO 7000

C. MECHANICAL REMOVAL

a. Vacuum truck

Cost: $546.00 (tank not included) (incl. sales tax)

Manufactured by:
PLAST AB CIPAX
Bredaryd, Sweden

The toilet is charged with 3 gallons (13.5 litres) of water, poured manually into a reservoir behind the seat. Waste falls directly into the tank. The bowl is cleaned with water which is recirculated for future use. A small amount of water, 3 ounces (0.1 litres), is left to form a water seal. Once a week the reservoir is emptied into the tank and refilled. Following each use, an electrically driven fan (35 watts) vents the tank. Water is sprayed into the bowl by an electric pump (40 watts). Both pump and fan are 24 v, from 220 v by a 100 watts transformer. The tank is emptied at intervals by a vacuum truck, or could drain to a tile-field. The unit is of polyethylene plastic.

Assumption: Operating time of the fan (5 min/visit)
Operating time of the water-spraying pump (0.5 min/visit)

Saving in Energy: -(35 W/p x 5/60 hr/visit + 40 W/p x 0.5/60 hr/visit)
x 4 p /home x 5 visit/d x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$0.77/home/yr

OJO 7100

C. MECHANICAL REMOVAL

a. Vacuum truck

Cost: $364.00 (incl. sales tax)

Manufactured by:
PLAST AB CIPAX
Bredaryd, Sweden

This unit is connected to a water-supply line and uses 1.5 pints (0.8 litres) each time the toilet is used, to clean the bowl. A small amount of this water forms a water-seal in the bottom of the bowl. Flushing is accomplished by lifting handle. No electricity or chemicals are used. The tank is vented, and must be emptied at intervals.

TURQUO

C. MECHANICAL REMOVAL

b. Chemical privy

Cost: Unknown

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e, France

This is a "luxury" model designed in the so-called Turkish manner, probably the only healthful defacating position known to man. The unit is connected to a water-main and drained via a 1½" (38.1 mm) diameter pipe to the tank, vault or leaching pit. The bowl is flushed by syphonic action of 2.5 gallons (12 litres) of water. Chemicals are added once a month. Overflow to the drain-pipe is automatic. The unit is of polyester plastic and designed to be installed flush in the floor. It requires about 16" (40 cm) below the floor to accomodate the reservoir. There is no vent.

MANOIR

C. MECHANICAL REMOVAL

b. Chemical privy

Cost: $272.00

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e, France

This is a "luxury" model designed to look, and function, somewhat like a flushing toilet. The unit is connected to a water main, and is drained via a 1½" (38.1 mm) diameter pipe, to a tank, vault or leaching pit. The bowl is flushed by syphonic action, unlike most chemical toilets, which requires more 2.5 gallons (12 litres) water for each use. Chemicals are added. When not in use a water-seal is effected in the bowl. The unit is of polyester plastic.

CASTEL

C. MECHANICAL REMOVAL

b. Chemical privy

Cost: 182.00

Manufactured by:
Waterlo
41, Rue Censier, Paris 5e. France

This is a fixed toilet that would be connected to a leaching-pit, tank or vault via a pipe network. It is connected to a water supply pipe by a 1½" (38.1 mm) diameter pipe, and uses 1 quart (1.1 litres) of water for each use, to rinse the bowl. An over-flow mechanism empties the reservoir as water is added. Chemicals are added to inhibit decomposition and thereby, smell. There is no vent. A water-seal is effected when the toilet is not in use. The unit is of polyester plastic.

CAUSTICA 128 — C. MECHANICAL REMOVAL

Cost: $98.00 — b. Chemical privy

Manufactured by:
Establissements P. Mimault
45, Rue du Fort, 94400 Vitry Sur-Sein, France

This is a vented chemical privy designed for fixed use, for 34 people. It is made out of enamalled steel and weighs 66 pounds (30 kg). The unit can be emptied manually into a bucket, or can be connected to a drainage pipe. A splash pan protects the user and is manually opened. This also moves a paddle in the bottom of the tank. The toilet is sealed when not in use. Water and chemical are added after each emptying. A smaller portable and lighter (44 pounds, 20 kg) model without any vent and for use by 1-2 persons, Caustica 65, is also made by this company for $63.00.

CLOSENET STANDARD — C. MECHANICAL REMOVAL

Cost: about $50.00 — b. Chemical privy

Manufactured by:
Etablissements R. Derouineau
Moulin de Pelissey, 33-Gradignan, France

This is a fixed toilet which functions without any water and is connected to a holding-tank or leaching-pit. A constant level of water is maintained in the toilet. Chemicals are added at frequent intervals. Each time the seat is lifted it activates a pump, and 1-2 quarts (1-2 litres) of fluid are automatically pumped out. An equal amount of water is added after each use, to clean the bowl. The outlet pipe is small-diameter and can be connected to any drain. All parts are of plastic, and the toilet weighs 18 pounds (8.1 kg).

MAGIC FLUSH

C. MECHANICAL REMOVAL

c. Recirculating fluid toilet

Cost: Unknown

Manufactured by:
Monogram Industries, Inc.
1165 East 230th Street, Carson, California 90745

This system is now in production in Canada by:
Monogram Sanitation Products of Canada Ltd.
3332 Mainway, Burlington, Ontario

This system is currently being developed and is not yet on the market. An inert, water-white fluid is used with conventional flush toilets. It is absolutely immiscible to human waste, and is readily separated from the waste and used over and over again for flushing. The separated wastes are stored in a small tank for periodic collection by vacuum truck. It is estimated that a 320 gallon (1440 litres) will contain the waste of a family of four with semiannual service.

BIO-FLO 512

C. MECHANICAL REMOVAL

c. Recirculating fluid toilet

Cost: $329.00

Manufactured by:
Pure Way Corp.
301-42nd Avenue, East Moline, Illinois 61244, U.S.A.

This toilet is manufactured from fibreglass and plastic. The design of the unit provides a large compartment for the deposit of the body waste plus paper. Alternating layers of gravel and activated charcoal are placed in the bottom of this compartment. The liquid percolates to the second chamber which similar, though smaller. The overflow from the second chamber flows through a weir to the third pump chamber, where it is manually pumped to flush the toilet bowl. The discharge flows via a fourth chamber to a tile field.
Once a week a packet is added to the first chamber of the unit, which consists of freeze dried aerobic and anaerobic bacteria and enzymes, which are intended to increase the bacterial and chemical action taking place.
The amount of effluent is very small, averaging 0.2 liters/person/day.
The operating cost is less than 4 cents per day; the activated charcoal and gravel ought to be replaced about every two years, at which time the unit is primed with 15 gallons of water. The unit has been tested with as many as 13 people using it at one time.

BIOCYCLE MK 1 — C. MECHANICAL REMOVAL

c. Recirculating fluid toilet

Cost:: $230.00

Manufactured by:
Biodynamics Ltd.
Camac Buildings, Ballymount Road,
Clondalkin, Co. Dublin, Ireland

This toilet is manufactured out of ABS plastic and contains four compartments which make up the filtration and recycling process. The same fluid is used for flushing the bowl. Digestant compound is added periodically to the first compartment. The manufacturer's brochure describes this as follows:

> "... selected micro-organisms, active enzymes, buffers, bacteria and activating agents effectively decomposes all organic waste-entirely within the unit itself. It completely neutralizes and liquifies human waste and the resulting effluent becomes clean, clear water."

It is not made clear how this is achieved.

SHALLOW TRAP (LOW TRAP) — C. MECHANICAL REMOVAL

d. Water-borne network

Cost: $75.00

Manufactured by:
American Standard Water Saving Elongated Cadet
U.S.A.

This device is designed to use approximately one-third less water than ordinary toilets. It is similar in appearance and cost to the standard model except for a noticeable smaller tank. Less water is required for flushing due to the special design of the bowl. (shallower trap)

BATCH-TYPE FLUSH VALVES (2) IN DUAL CYCLE — C. MECHANICAL REMOVAL

d. Water-borne network

Cost: $145.00

Manufactured in:
U.S.A.

This device is also called "two flush valve with toilet". It is widely used in commercial buildings and apartments, but could also be used in homes. The valves can be set to deliver from 0.5 gal. to 4 gal./cycle, usually with 3.5 gal./flush for solids on 2.5 gal./flush for urine. A 3/4" copper tube water line is used in place of a 1/2" line. The use of these valves would result in an average water saving of 1.5 gal./operation.

BATCH-TYPE FLUSH VALVE (1) — C. MECHANICAL

Cost: $97.50 — d. Water-borne network

Manufactured in:
U.S.A.

Other names for this design are "automatic flush valve water closet" and "one flush valve with toilet". It is essentially the same idea as last device except for a single flush valve with 3.5 gal./flush in place of the conventional tank. It also requires a larger diameter water line (3/4" copper tube" than is now used to supply a flush tank (1/2").

URINAL WITH BATCH-TYPE FLUSH VALVE — C. MECHANICAL

Cost: $125.00 — d. Water-borne network

Manufactured in:
U.S.A.

This is the wall-type urinal of compact design for home installations. These urinals have batching-type flush valves set at 1.5 gal. water per use. Two limitations of the use of this device are:
1) additional bathroom space would be required.
2) the units would serve male household members only.
Female urinals are used on a limited basis in a few office buildings and factories, but their use in homes is not warranted.

DUAL CYCLE WATER CLOSET (BRITISH TYPE) — C. MECHANICAL REMOVAL

Cost: about $17 — d. Water-borne network

Manufactured by:
Ideal-Standard Limited
Ideal Works, Hull, England

The British type dual cycle water closet is also called "dual flush cistern" in England. It is designed to save water while maintaining the advantages of flushing toilets. The cistern releases either one or two gallons of water according to requirements. One gallon is flushed if the cistern handle is released immediately after pressing down, two gallons if the handle is held down until the flush is completed.

DUAL CYCLE WATER CLOSET (ECONO-FLUSH) — C. MECHANICAL REMOVAL

Cost: $14.00 — d. Water-borne network

Manufactured in:
U.S.A.

This toilet device consists of two interconnected plastic tank open at the bottom which are positioned inside the toilet tank, and a handle/lever assembly incorporating a unique valve arrangement. With the exception of some of the newer toilet models, which have special flush valves, most standard models with standard flush valves will accomodate this particular device. The Econo-Flush operates a light flush (push the handle up) for the liquid waste and a normal flush (push the handle down in the usual manner) for the solid waste.

DUAL CYCLE WATER CLOSET (SINK-BOB)

C. MECHANICAL REMOVAL

d. Water-borne network

Cost: $4.00

Manufactured in:
U.S.A.

This device consists of a polystyrene float and lead sinker connected to the float stem by a split brass ring. As with the Econo-Flush device, most standard toilet models will accomodate the Sink-Bob. The Sink-Bob attaches to both rod and flapper-type seals at a point just above the flush valve. The device operates a light flush (the handle is tripped in the normal manner) for the liquid waste and a normal flush (the handle is held down during the entire flushing operation) for the solid waste.

DUAL CYCLE WATER CLOSET (SAVEIT WATER SAVER)

C. MECHANICAL REMOVAL

d. Water-borne network

Cost: $6.00

Manufactured in:
U.S.A.

This device needs to convert a toilet to dual-cycle operation with some modification and provides a reduced flush of approximately 50%. It consists of a pre-folded plastic sheet which is formed around the flush valve and secured with two anchor rods. When flushing occurs, the flush valve closes prematurely as approximately one-half of the water in the tank is blocked from gaining access to the drain.

TOTO 5

C. MECHANICAL REMOVAL

d. Water-borne network

Cost: Unknown

Manufactured by:
Toto ltd.
458 Shinozaki, Kokura-Ku
Kitakyushu, 802 Japan

This is a conventional flushing toilet, except that the tank-cover is a washbasin. That is, the dirty wash-water (grey-water) is used for flushing waste (black-water). The saving in water would be in the order of 25%, as well as there being a saving in cost and space, since two bathroom fixtures occupy the space of one.

M S U 2

C. MECHANICAL REMOVAL

d. Water-borne network

Cost: $50.30

Designed by:
Minimum Cost Housing Group
McGill University
Montreal (1971)
Canada

The Minimum Sanitary Unit 2 uses a wash-basin as a cistern cover. An experimental model was made out of sulphur concrete, but could also be in porcelain or fibreglass.

NIBO

C. MECHANICAL REMOVAL

d. Water-borne network

Cost: Unknown

Manufactured by:
Nibo Plast
Montevideo, Uruguay

This cistern is made out of the flexible thermo-plastic and is designed to reduce the number of moving parts. To flush the toilet one presses against the body of the cistern by hand, and water flows into the down-pipe following the principle of physics of "connected vessels". This gives the user control over the amount of water flushed, whether for solid or liquid waste. In addition, this type of cistern will not waste water through slow leaking, or if the handle is kept down, as conventional models sometimes do.

BRICK-IN-THE-TANK

C. MECHANICAL REMOVAL

Cost: $0.06

d. Water-borne network

Do-it-yourself method
for saving water.

CHERRY HILL, N.J. (Associated Press). -
Six months ago, Tilly Spetgong, a serious gal with a goofy idea, walked into city council carrying a brick. Councilman Steve Morgan ducked under his desk. "He must have thought I was going to throw it," she said, "but all I wanted was to put one into every toilet tank in town." The unusual proposal to save water stunned the council, but it was approved. And it so convulsed this residential community of 65,000 across the Delaware River from Philadelphia that it swiftly assisted the scheme - to become probably the first with a brick in nearly every toilet.
The idea is that the brick will take up space in the toilet tank, displacing a small amount of water that is not necessarily needed for flushing.
"It was wacky idea that got people laughing, and also made them aware that people pollute and people can conserve," said Mrs. Spetgong, a 44-year-old mother of two who used to raise chickens and now, admittedly, "raises the dickens" as a member of the conservation advisory board.
The council anteed up $2,000 to buy 34,000 hardened bricks, the kind that won't break up in any kind of water and enough for every toilet in the town's 17,000 homes.
Last weekend, about 175 persons distributed 27,000 bricks, two to a house. They will finish this Saturday.
Mrs. Spetgong said: "If the average family of four flushes a total of 20 times a day we would save 34 million gallons of water every year in Cherry Hill."

PEDAMATIC 2

C. MECHANICAL REMOVAL

Cost: $85.00

d. Water-borne network

Manufactured by:
Ownes Products
1002 East 19th Street, Kansas City, Missouri 64108, U.S.A.

This is a conventional flush toilet that is pedal activated, a considerably more hygenic practice than hand operated mechanisms. The pedal has two positions: one that opens the flush water valve but does not open the bowl outlet, and a second, fully depressed, for opening the seal and flushing the toilet. The added control by the user over the amount of water used, as well as the absence of the usual trap, ought to result in less water being consumed, though this has not been substantiated by documentation.

VACU-FLUSH (SINGLE HOME) — C. MECHANICAL REMOVAL

Cost: $710.00 — e. Vacuum network

Manufactured by:
Mansfield Sanitary, Inc.
Perrysville, Ohio 44864, U.S.A.

This is a marine sanitation system that operates on small quantities of water (1 liter) for flushing by using a vacuum to move the waste through small diameter pipes, irrespective of gravity.

Assumption: motor size (1/4 hp); electricity consumption (55.8 KWH/month)

Saving in Energy: - 55.8 KWH/month/home x 12 month/yr x $0.0325/KWH
= -$21.76/home/yr

VACUUM FLUSH (100 HOME) — C. MECHANICAL REMOVAL

Cost: $524.00 — e. Vaccuum network

Manufactured in:
Sweden

The vacuum flush toilet for the individual home is too expensive because of the high cost of the accompanying equipment when used for single homes. It can be justified economically for groups of families (e.g. 100 homes). A central collection tank with dual vacuum pumps is used.

Assumption: motor size (5 hp); electricity consumption (12.2 KWH/month)

Saving in Energy: -12.2 KWH/month/home x 12 month/ys x $0.0325/KWH
= -$4.76/home/yr

ELECTROLUX VACUUM SEWAGE SYSTEM — C. MECHANICAL REMOVAL
e. Vacuum network

Cost: 1 toilet - $1177 (incl. sales tax) 5 hseholds - $4190 (incl. sales tax)
2 toilet - $1738 (incl. sales tax) 10 hseholds - $6579 (incl. sales tax)

Manufactured by:
Electrolux
Environmental Systems Division,
S-105 45, Stockholm, Sweden

The Electrolux Company in Sweden has developed a Vacuum system in the early 1950's, which is a method of transporting sewage by vacuum, thus eliminating a large volume of the normal flush water found in flush toilets.
The system has been applied at several different scales: in passenger railway cars of the Swedish State Railways, in a camping site with 83 toilets, and a small community of 273 houses.
The greatest advantages of this system are - the small amount of water used and consequently less waste to remove from holding tanks; less excavation, smaller diameter piping required; smaller holding tank required. It is estimated that a vacuum system is 25%-40% cheaper than a gravity system.

Assumption: motor size (1/4 hp); percentage operating time (30%); operating time (1 min/visit)

Savings in Energy: Same as VACU-FLUSH (SINGLE HOME)
= -21.76/home/yr

DESTROILET

D. DESTRUCTION

Cost: $465.00

a. Incinerating toilet

Manufactured by:
La Mere Industries Inc.
Walworth, Wisconsin 53184, U.S.A.

A number of models are available, differing only in the power source-propane or natural gas, and 115 v. A.C. or 12 v. D.C. Electricity is used to power a blower that evacuates smoke and cools down the unit. Gas is used as fuel to burn the waste. The unit is built of porcelain enamel and steel and weighs 100 pounds (45 kg). With 4-6 people, the ashes will have to be cleaned out weekly, Each cycle uses one quarter pound of gas, and the capacity of the system is about 60 uses a day.

Assumption: motor size (70 W); operating time (45 min/use); frequency of use (4 uses/day);

Saving in Energy: (-1/4 lb/p/d x 7.5 ¢/lb x 4 p/home x 365 d/yr)+(-70W x 0.001KW/W x 45 min/visit x 1/60 hr/min x 4 visit/d/home x 365 d/yr x $0.0325/KWH)
= -$29.87/home/yr

ELONETTE

D. DESTRUCTION

Cost: $364.00 (including sales tax)

a. Incinerating toilet

Manufactured by:
AB Elonette
Grevgatan 50, 114 58 Stockholm, Sweden

This unit (2200 W. 220 V. 1-phase) has a 30 minute burning cycle, and no cooling cycle. Special paper bags, with small amount of sawdust are used to protect the bowl and facilitate burning. Operation cost is about 4 cents per visit (Sweden).

Saving in Energy: -4¢/visit x 4 visit/d/home x 365 d/yr
= -$58.40/home/yr

TOARETT — D. DESTRUCTION

Cost: $325.00 (including sales tax). — a. Incinerating toilet

Manufactured by:
Ageno Produktions AB
Knistallvagen 56, 126 41 Hagersten, Sweden

This incinerating toilet operates on gas. The burning time is only 8 minutes and produces little odour. Operating cost is 8 cents per visit (Sweden).

Saving in Energy: -8¢/visit x 4 visit/d/home x 365 d/yr
= -$116.80/home/yr

ECETT — D. DESTRUCTION

Cost: $781.00 (incl. sales tax) — a. Incinerating toilet

Manufactured by:
AB Hakanssons Industrier
Box 126, 662 00 Amal, Sweden

This combustion toilet is electronically powered (3-phase 380 v. or 3-phase 220 v.) and has a 40 minute burning time plus 30 minute cooling period, (fan). One burning cycle can accomodate up to 4 visits. A special bag is used to protect the bowl, and is incinerated together with the waste. Some nuisance is caused by the odour of the smoke. Swedish authorities do not allow incinerating toilets where the house is less that 640 feet (195 m) from the nearest neighbour. Operating cost is about 6 cents per visit (Sweden).

Saving in Energy: -6¢/visit x 4 visit/d/home x 365 d/yr
= -$87.60/home/yr

ELEKTRO STANDARD — D. DESTRUCTION

Cost: $847.00 (incl. sales tax) — a. Incinerating toilet

Manufactured by:
Elektro Standard AB
Box 26, 641 00 Katrineholm, Sweden

The burning time of this unit is 30 minutes plus 45 minutes cooling-off (fan). Burning is repeated from the start for visits made during the burning period. Special paper inserts are used. Electrical cost is about 5 cents per visit (Sweden). Burner - 2700 watts, fan - 70 watts 3-phase 380 v.

Saving in Energy: -5¢/visit x 4 visit/d/home x 365 d/yr
= -$73.00/home/yr

CLIVUS — E. DEOCMPOSITION

Cost: $678 - $875 (incl. sales tax) — a. Compost privy

Now available in U.S.A.
Clivus Multrum Inc.
14 Eliot Street, Cambridge, Mass. 02138
Cost: $1200

Manufactured by:
Clivus AB
Tohstigen 6, S-135 00 Tynesòe, Sweden

This is a system for the biological degredation of organic waste, with a built-in garbage chute and toilet. It consists of chutes from the kitchen and toilet, an exhaust duct and a decomposition chamber. It will handle all solid and liquid organic wastes other than bath, dish and laundry water. Its output is fertilizer. The entire unit is of fiberglass and was developed for remote Scandinavian weekend houses.

MULL-TOA — E. DECOMPOSITION

Cost: about $350.00 (incl. sales tax) — a. Compsot privy

Available from:
Hans Kr. Nielsen
Sorkedalsveien 22, Oslo 3, Norway

This is a composting toilet that uses a stream of warm air to effect the aerobic decomposition of the waste. A 180 watt motor (running at 42 v. via a transformer from 220 v) re-circulates warm air though the waste up to 250 times. As the air becomes saturated it is automatically discharged through a ventilation stack. The system moves 42 c.f.m. (1200 litres/minute) at 86°F (30°C), ideal for microbiological growth. All liquid waste is vented with the saturated air. For a family of 3-4 persons, the drawer would have to be emptied once a year. The resultant mould is suitable for fertilizer. No water or chemicals are added. Kitchen waste may be put in the toilet to encourage microbes. At least 28" (71 cm) clearance is required in front of the toilet for the pull-out drawer. The body is of polyethylene plastic.

Saving in Energy: -180 W/home x 0.001 KW/W x 24 hr/d x 365 d/yr
= -$15.77/home/yr

SANITERM — E. DECOMPOSITION

Cost: $742.00 (incl. sales tax) — a. Compost privy

Manufactured by:
AB Electrolux
Luxbacken 1, 112 62 Stockholm, Sweden

This toilet dries and decomposes the waste by recirculating heated air. After 4 - 8 weeks the "ash" is moved to the rear of the decomposing by means of a hand-operated mill. When the dried material is re-moistened (by urine) there is some smell, but no pathogenic growth. In any event, no odours enter the bathroom and the vented air is first passed through a charcoal filter. Electricity cost for average use is 24 cents per day (Sweden).

Saving in Energy: -24¢/d/home x 365 d/yr
= -$87.60/home/yr

MULLBANK — E. DECOMPOSITION

Cost: $308.00 (incl. sales tax) — a. Compost privy

Manufactured by:
Inventor AB
Prastgatan 42, 831 00 Ostersund, Sweden

The decomposition of waste is accelerated by electrical heating coils in the bin. Decomposition is not total, and the ash, which should be removed twice a year, should be composted or mixed in garden-soil, to complete the process. Electricity cost for average use is 6 cents per day (Sweden).

Saving in Energy: -6¢/d/home x 365 d/yr
=-$21.90/home/yr

MULTRUM — E. DECOMPOSITION

Cost: Unknown — a. Compost privy

As far as we have been able to ascertain, no working model of this design has been built, so the operational capability remains unknown. The small size of the chamber could cause problems

Designers:
SCAN PLAN
3 Sankt Kjelds Gade, DK-2100 Copenhagen, Denmark

The Multrum devise for biological destruction of human waste was invented in Sweden about 30 years ago. The version shown here was developed by SCAN PLAN for use in African communities. It uses simple materials and techniques. Water is supplied by the urine and human and kitchen wastes mix with a layer of peat, grass or leaves. Humidity and carbon dioxide are vented out. The aerobic process is supplied air by the channels. The volume of the refuse is reduced to 10% of the original, and slides to the lowest part of the container. The residue, consisting of soil, humus and nutritive salts, is removed once every one or two years, to be used as fertilizer. No water, power or chemical is used.

FARALLONES PRIVY

E. DECOMPOSITION

Cost: under $100.00

a. Compost privy

Plans available from below address for $1.50 postpaid

Designed by:
Farallones Institute
Point Reyes Station, California 94956, U.S.A.

This do-it-yourself toilet is most suitable for a rural location, both because of its area, and the operation (the manure requires to be turned once a month). Simple and cheap.

KERN COMPOST PRIVY

E. DECOMPOSITION

Cost: Unknown

a. Compsot privy

Designed by:
Ken Kern
P. O. Box 550, Oakhurst, California 93664 U.S.A.

Reference:
The Owner-Built Homestead
by Ken Kern 1974

This is a design that was first published in "The Owner-Built Home" and subsequently, with modifications, been built by Ken. It incorporates a sauna and water heater on the upper level, and a shower and toilet on the lower floor. The composting chamber, below the floor, is divided in two compartments. A metal baffle directs the waste from one to the other, and twice a year alternate compartments are cleared of compost, The compost may have to be turned by hand from time to time. The water from bathing and washing is diverted from the toilet and separately carried to a tile field.

ECOL SANITARY UNIT

E. DECOMPOSITION

Cost: $175.18

b. Continuous aeration

Designed by:
Minimum Cost Housing Group
Brace Research Institute, McGill University, Montreal, Canada

This toilet is based on the idea of recycling aerated water for use in flushing. A 12 v. aquarium pump, powered by batteries changed by a wind-machine, aerates the waste on a continuous basis, in a re-used 45 gallon (202 litres) oil drum that is buried beneath the toilet. A pipe leading to the outside vents the gases to the air. It is estimated that solids will build up at the rate of 2" - 3" (5-10 cm) per year. Dirty wash water is also used for flushing. This unit has been in operation for one year and it is too early yet to have definitive data on success of operation. This design is included to show a direction for research.

ECO-HOUSE

E. DECOMPOSITION

Cost: Unknown

c. Algae digester

Designer: Graham Caine
Street Framhouse, Kidbrooke Lane, Eltham
London, S.E.9, England

An ecological house, under construction (1973), using an intermediate technology approach.

PRIMARY DIGESTER
This is an airtight tank which receives all the liquid and organic "waste" from the household. It produces a gas suitable for burning and coupled with the gas from the algae digester; cooking requirements should be met. For details of small digesters see "MOTHER EARTH NEWS" No 3.

ALGAE TANK
This tank receives the displaced liquid effluent from the Primary Digester. The algae feed with the bacteria, providing the oxygen for the bacteria to metabolise the organic matter at the same time gaining an organic loading through photosynthesis. This organic loading in the form of carbohydrate (carbon, hydrogen and oxygen) is later broken down to produce methane (CO_2). Also, during this stage, any pathogenic viruses are exposed to ultra violet light from the sun and are thus destroyed.

ALGAE DIGESTER
In this digester the algae break down to produce gas for cooking and an ORGANIC nutrient solution that is fed to the vegetable beds. This digester, like the Primary Digester is connected to a solar flat plate energy absorber which is a simple panel vadiator exposed to the sun. Some experiments they've done with these sort of heaters show remarkable results with water being tested 80°F in January and up to 160°F since April. This was with 18 square feet of radiater panel connected to 30 gallons of water. For more details see Architectural Design, July issue.

WHO METHANE PLANT — F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: Unknown

Reference:
World Health Organization
Geneva, Switzerland

The WHO publication "Composting" gives plans for constructing a methane-recovery plant that combines human-waste with animal wastes, to produce methane gas. Horses and cows produce about 10-16 tons of manure per year, while humans add only 30-60 pounds (14-28 kg) per capita per year, however human waste is rich in nitrogen and phosphorus, necessary for biological digestion and methane production from cellulose and other materials with a high carbon content. A ton of waste will normally yield about 65-90 cubic yards (50-70 cubic metres) of gas per digestion cycle, though this depends on the temperature, and cycles can vary from one to twelve months. An efficient size of digester is 10 cubic yards (8 cubic metres). The methane gas can be used for domestic cooking, heating and lighting, or as fuel for providing power. Initial cost is relatively high, but operating and maintenance costs are insignificant.

Assumption: human-waste produced (0.5 lb/person/day);
average yield of gas production (60 cu. meter/ton waste)

Saving in Energy: +0.5 lb/p/d x 4 P/home x 365 d/yr x 0.0005 ton/lb x 60 m^3/ton x $(3.28)^3$ ft^3/m^3 x 0.001 MCF/ft^3 x \$1.50/MCF
= +\$1.16/home/yr

MELANESIAN METHANE DIGESTER — F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: \$300.00

Designed by:
George L. Chan
University of Papua, New Guinea

This is a small, 300 gallon (13,500 liters) rural installation which is designed to accommodate waste from 30 pigs, 30 chickens, as well as human waste. The gases formed in the anaerobic digester are 60-70% methane, and are stored in the gas cover, which is painted black to take advantage of solar heat to encourage digestion. The waste from this digester will yield about 10 cubic meters of gas daily (in the Melanesian region), adequate to provide cooking, lighting, and refrigeration for a family of six.

This digester has been installed in Fiji and on New Guinea, and is used in conjunction with algae ponds into which the effluent from the digester is discharged. The algae provide protein and vitamins to enrich animal feed. The effluent from the algae ponds is in turn used for fish and shellfish cultivation.

Saving in Energy: +10 m^3/d/home x 365 d/yr x $(3.28)^3$ ft^3/m^3 x 0.001 MCF/ft^3 x \$1.50/MCF
= +\$193.20/home/yr

FLO-THRU

F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: $1,020.000

Manufactured by:
On-Site Sewerages Inc.
P.O. Box 567
Lafayette, Indiana 47901, U.S.A.

This extended aeration system recycles the treated fluid to be re-used as flushing water. A grinder below the toilet pulverizes the solid waste and a pump re-cycles the water; a second pump runs a continuous aeration device within the treatment/filtration tank. The 300 gallon (1130 liters) tank is filled with water on installation, and subsequently there is no need for continuing water supply.
The continuous aeration toilet has been a continuing obsession of Carl Boester's since 1952 when he introduced his first sewerless toilet.

Assumption: motor size of the pump (1/4 hp)

Saving in Energy: -1/4 hp x 0.7457 KWH/hp x 24 hr/d x 365 d/yr x $0.0325/KWH
= -$53.08/home/yr

CROMAGLASS C-5

F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: Unknown

Manufactured by:
Cromaglass Corporation
Williamsport, Penna. 17701, U.S.A.

This is a small-scale sewage treatment plant for treating water-borne waste of one household, and discharging a semi-clear, odourless fluid. The unit is housed within a 830 gallon (3755 litres) fibreglass tank and weighs 437 pounds (196 kg). Aerobic decomposition is achieved by recirculating the waste-water and mixing it with warm air, pumped from the outside. The activated sludge is allowed to settle, and the "95% treated" fluid is pumped out, into a water course or tilefield. The unit operates on a ¼ HP electric motor. The company makes a larger unit that will handle the waste from 25 people a day (Model CA-1510)

Assumption: motor size of the pump (¼ hp)

Saving in Energy: Same as FLO-THRU
= -$53.08/home/yr

BIO-DISC

F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: $4300.00 (5 person unit)

Manufactured by:
Ames-Crosta Mills (Canada)
105 Brisbane Road, Downsview, Ontario, Canada

This British system, invented in 1963, features a series of slowly rotating discs onto which the sewage adheres to form a biologically active surface that feeds upon the sewage impurities. The sludge settles to the bottom of the tank, and requires emptying two or three times a year. Actual tests indicate that within a range of influent BOD_5 strengths of up to 700 mg/l, effluent strength are 10-20 mg/l.
The plant requires motive power to drive the rotating discs; consumption is about 20 watts/person/day, which compares favorably with the 40-160 watts/person/day consumed by extended aeration type plants.
A five person unit costs $860 per person, however economies of scale reduce this cost to $110 per person for a five hundred person installation (the largest suggested by the manufacturer).

Saving in Energy: -20 w/p/d x 4 p/home x 365 d/yr x 0.001 KW/W
x $0.0325/KWH
= -$0.95/home/yr

AQUAROBIC

F. HOUSEHOLD WASTE TREATMENT PLANT

Cost: $1700 - $2000 (incl. installation)

Manufactured by:
Waltec Industries Limited
Wallaceburg, Ontario, Canada

This is essentially a household version of a sewage treatment plant, using a 3-stage system. In the first tank there is 2 step aeration of the sewage, to destroy the pathogenic bacteria by aerobic action. The air-activated microorganisms from an 'activated sludge' that is allowed to settle in a compact filter bed. On a periodic basis the sludge is returned to the aeration tank to maintain the action. It is estimated that excess sludge will have to be removed every 4-8 years depending on use. The system is designed to handle waste from up to 8 people. The water out-put can be discarded into water-courses or into the soil with no danger of pollution, but is not designed to be re-used.

Assumption: motor size (¼ hp)

Saving in Energy: -¼ hp/home x 0.7457 KW/hp x 24 hr/d x 365 d/yr x $0.0325/KWH
= -$53.04/home/yr

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