ENERGY CONSUMPTION AND POPULATION[1]

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1. Introduction

The conventional approach to the energy-population nexus is that population levels determine energy demand -- the larger the population, the more the total energy required, with the magnitude of this total energy depending on the per capita energy consumption. In other words, population exogenously determines energy consumption.[1]

This exogenous impact of population on energy is the obvious aspect of the population-energy connection. If, however, energy consumption and population growth are a dialectical pair -- each transforming the other, and each being the effect when the other is the cause -- then the pattern of energy consumption should also have an effect on population growth, the other side of the coin. That energy strategies can contribute to a reduction of the intensity of the population problem has often been mentioned. But, the linkage has not been elaborated sufficiently; hence, an attempt here to explore this other dimension of the energy-population nexus.

The exploration must begin with the general preconditions for a decline of fertility. To quote Coale[2]:

- "Fertility must be within the calculus of conscious choice. Potential parents must consider it an acceptable mode of thought and form of behaviour to balance advantages and disadvantages before deciding to have another child."
- "Reduced fertility must be advantageous. Perceived social and economic circumstances must make reduced fertility seem an advantage to individual couples".
- "Effective techniques of fertility reduction must be available. Procedures that will in fact prevent births must be known, and there must be sufficient communication between spouses and sufficient sustained will, in both, to employ them successfully".

The central hypothesis of this paper is that energy consumption patterns influence the rate of population growth through their effect on the desired number of births in a family and the relative benefits of fertility. Ultimately, these patterns tend to retard or accelerate the demographic transition.[3] This hypothesis will be examined by exploring the influence of energy consumption on population growth at two levels -- the micro-level of villages and the macro-level of global levels.

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2. The Energy-Population Nexus at the Village Level

2.1 Village Energy Consumption Patterns

There have been several studies of the patterns of energy consumption in villages. Among the earliest of the studies was that of six villages in the Ungra region of Tumkur District, Karnataka State, South India.[4]

Pura (latitude: 12 49'00" N, longitude: 76 57'49" E, height above sea level: 670.6 m, average annual rainfall: 127 cms/year, population (in September 1977): 357, households: 56) is one of the villages in Kunigal Taluk, Tumkur District, Karnataka State, South India.

The energy-utilizing activities in Pura consist of[5]:

- agricultural operations (with ragi and rice as the main crops),
- domestic activities -- grazing of livestock, cooking, gathering fuelwood and fetching water for domestic use particularly drinking,
- lighting and
- industry (pottery, flour mill and coffee shop).

These activities are achieved with human beings, bullocks, fuelwood, kerosene and electricity as <u>direct</u> sources of energy.

An aggregated matrix showing how the various energy sources are distributed over the various energy-utilizing activities is presented in Table 1[6].

Table 1. Pura energy source-activity matrix (x 10^6 kcals/year)

	Agriculture	Domestic	Lighting	Industry	Total
Human	7.97	50.78	--	4.97	63.72
(Man)	(4.98)	(20.59)	--	(4.12)	(29.69)
(Woman)	(2.99)	(22.79)	--	(0.85)	(26.63)
(Child)	--	(7.40)	--	--	(7.40)
Bullock	12.40	--	--	--	12.40
Fuelwood	--	789.66	--	33.93	823.59
Kerosene	--	--	17.40	1.40	18.80
Electricity	6.25	--	2.65	0.71	9.61
Total	26.62	840.44	20.05	41.01	928.12

Total energy = 928 x 10^6 kcal/year; = 1.079 x 10^6 Wht/year; = 2955 kWht/day; = 8.28 kWht/day/capita

The matrix yields the following ranking of sources (in order of percentage of annual requirement): (1) fuelwood 89%, (2) human energy 7%, (3) kerosene 2%, (4) bullock energy 1%, (5) electricity 1%. The ranking of these activities is as follows: (1) domestic activities 91%, (2) industry 4%, (3) agriculture 3% and (4) lighting 2%.

Human energy is distributed thus: domestic activities 80% (grazing livestock 37%, cooking 19%, gathering fuelwood 14%, fetching water 10%), agriculture 12%, and industry 8%. Bullock energy is used wholly for agriculture including transport. Fuelwood is used to the extent of 96% (cooking 82% and heating bath water 14%) in the domestic sector, and 4% in industry. Kerosene is used predominantly for lighting (93%), and to a small extent in industry (7%). Electricity flows to agriculture (65%), lighting (28%), and industry (7%).

There are several features of the patterns of energy consumption in Pura which must be highlighted.

- What is conventionally referred to as commercial energy, i.e., kerosene and electricity in the case of Pura, accounts for a mere 3% of the inanimate energy used in the village, the remaining 97% coming from fuelwood.[7] Further, fuelwood must be viewed as a non-commercial source since only about 4% of the total fuelwood requirement of Pura is purchased as a commodity, the remainder being gathered at zero private cost.
- Animate sources, viz., human beings and bullocks, only account for about 8% of the total energy, but the real significance of this contribution is revealed by the fact that these animate sources represent 77% of the energy used in Pura's agriculture. In fact, this percentage would have been much higher were it not for the operation of four electrical pumpsets in Pura which account for 23% of the total agricultural energy.
- Virtually all of Pura's energy consumption comes from traditional renewable sources -- thus agriculture is largely based on human beings and bullocks, and domestic cooking (which utilizes about 80% of the total inanimate energy) is based entirely on fuelwood.[8]
- However, the environmental soundness of this pattern of dependence on renewable resources is achieved at an exorbitant price: levels of agricultural productivity are very low, and large amounts of human energy are spent on fuelwood gathering (on the average, about 2-6 hr and 4-8 km per day per family to collect about 10 kg of fuelwood).
- Fetching water for domestic consumption also utilizes a great deal of human energy (an average of 1-5 hr and 1-6 km per day per household) to achieve an extremely low per capita water consumption of 17 litres per day.
- 46% of the human energy is spent on grazing livestock (5-8 hr/day/household) which is a crucial source of supplementary household income.
- Children contribute a crucial 30%, 20%, and 34% of the labour for gathering fuelwood, fetching water and grazing livestock respectively. Their labour contributions are vital to the survival of families, a point often ignored by population and education planners.
- Only 25% of the houses in the 'electrified' village of Pura have acquired domestic connections for electric lighting, the remaining 75% of the houses depend on kerosene lamps, and of these lamps, 78% are of the open-wick type.

- A very small amount of electricity, viz., 30 kWh/day, flows into Pura, and even this is distributed in a highly inegalitarian way -- 65% of this electricity goes to the 4 irrigation pumpsets of 3 landowners, 28% to illuminate 14 out of 56 houses, and the remaining 7% for one flour-mill owner.

Table 2 below shows the end-uses of human energy in Pura. It is obvious that the inhabitants of Pura, particularly its women and children, suffer burdens that have been largely eliminated in urban settings by the deployment of inanimate energy. For example, gathering fuelwood and fetching water can be eliminated by the supply of cooking fuel and water respectively. There are also serious gender and health implications of rural energy consumption patterns, which have been brought out clearly by Batliwala[9].

Table 2. End-uses of human energy in Pura

	Human activity	Human energy expenditure		
		Hours/year	Hours/day/ household	kcal/ year x 10^6
1.	Domestic	255,506	12.5	50.8
1.1.	Livestock grazing	(117,534)	(5.7)	(23.4)
1.2.	Cooking	(58,766)	(2.9)	(11.7)
1.3.	Fuelwood gathering	(45,991)	(2.3)	(9.1)
1.4.	Fetching water	(33,215)	(1.6)	6.6
2.	Agriculture	34,848	1.7	8.0
3.	Industry	20,730	1.0	5.0
	TOTAL	311,084	15.2	63.8

Since then, there have been innumerable studies of rural energy consumption patterns.[10] The actual numbers show differences depending upon the region of the country, the agro-climatic zone, the proximity to forests, the availability of crop residues, prevalent cropping pattern, etc., but the broad features of the patterns of energy consumption in Pura that have been highlighted above are generally valid.

2.2. Population Implications of Village Energy Consumption Patterns

To understand the population implications of these features of the patterns of energy consumption in villages, it is necessary to consider how these features influence the desired number of births in a family and the relative benefits and costs of fertility.

Whereas the exercise of choice in matters of fertility is a culture-dependent issue, and the awareness and availability of fertility-reduction techniques depends upon specific technologies and the success with which they are spread, the desired number of births and therefore the relative benefits and costs of fertility depend upon socioeconomic factors such as:

- infant mortality and the probability of offspring surviving -- the lower this probability, the larger the number of children aspired for and the greater the exposure of the mother to the possibility of additional pregnancies,
- the role of women in arduous time-consuming household chores -- the greater this role, the less the emphasis on women's education and the lower the age of marriage,
- the use of children for the performance of essential household tasks -- the greater the use of children for these tasks, the more they become essential for the survival of the household,
- the opportunities for children to earn wages -- such wage-earning children become desirable and wanted as economic assets.

These are only a few of the factors that enter the perceptions of advantages and disadvantages of larger family size and greater fertility. But, it is clear that the reduction of desired family size and fertility, and therefore the acceleration of the demographic transition, depends upon crucial developmental tasks such as increase of life expectancy, improvement of the environment (drinking water, sanitation, housing, etc.), education of women, diversion of children away from life-support tasks and employment to schooling, etc.

Almost every one of these socio-economic preconditions for smaller family size and fertility decline depends upon energy-utilizing technologies.

- Infant mortality has much to do with adequate and safe supplies of domestic water and with a clean environment.
- The conditions for women's education become favourable if the drudgery of their household chores is reduced, if not eliminated, with efficient energy sources and/or devices for cooking and with energy-utilizing technologies for the supply of water for domestic uses.
- The deployment of energy for industries which generate employment and income for women can also help in delaying the marriage age which is an important determinant of fertility.
- If the use of energy results in child-labour becoming unnecessary for crucial household tasks (such as cooking, gathering fuelwood, fetching drinking water, and grazing livestock), an important rationale for large families is eliminated.

From this standpoint, it is obvious that the prevailing patterns of energy consumption in villages such as Pura do not emphasize energy inputs for

- providing safe and sufficient supplies of drinking water,
- the maintenance of a clean and healthy environment,
- the reduction, if not elimination, of the drudgery of household chores traditionally performed by women,
- the relief of menial tasks carried out by children, and
- the establishment of income-generating industries in rural areas.

Thus, current energy consumption patterns exclude the type of energy-utilizing technologies necessary to satisfy the socio-economic preconditions for fertility decline. In fact, they encourage an increase in the desired number of births in a family and an increase in the relative benefits of fertility.

Alternative energy strategies can contribute to a reduction in the rate of population growth if they are directed preferentially towards the needs of women, households and a healthy environment.[11] Energy strategies must provide the mundane, but momentous, energy inputs that would encourage a smaller family size and lower fertility, and thereby facilitate the demographic transition. Otherwise, the strategies would be missing an opportunity to contribute to a reduction of the intensity of the population problem.

2.3 A Population-related Village-level Energy Intervention

An example of an energy intervention that is a small step towards establishing village-level conditions that would play a role in discouraging large families will now be described. Fortunately, the intervention is in the same village of Pura the energy consumption pattern of which has just been described.

The traditional system of obtaining water, illumination and fertilizer (for the fields) in Pura village is shown in Figure 1. This traditional system was replaced in September 1987 with a community biogas plant system[12] -- the main components and the flows of inputs/outputs of which are shown in Figure 2.

A comparison of the present community biogas plants system with the traditional system of obtaining water, illumination and fertilizer shows that the households are winners on all counts. Not only have the households lost nothing, but they have gained the following:

- deep-borewell water which is better and safer than the water from the open tank,
- less effort to get this improved water,
- reduction in the incidence of water-borne intestinal diseases (because of the safer water), and therefore noticeable improvement in the health of children
- better illumination than the traditional kerosene lamps or even the unreliable, low-voltage grid electricity,
- cheaper illumination for the households using kerosene lamps,
- less pressure on the women to finish their chores during daylight,
- improved fertilizer which has greater nitrogen content and is less favourable to the growth of weeds and proliferation of flies compared to farmyard manure,
- a dung delivery fee to those (mainly women and children) who deliver the dung to the plants and take back the sludge.

The system is still under development and has much further to go. The next stages include the provision of efficient cooking fuels/devices to households to reduce the burden of fuelwood gathering and the health hazards associated with current cooking patterns. But, even the first phase suggests the type of energy interventions that can influence the rate of population growth.

3. The Energy-Population Nexus at the Global Level

Over the past decade and a half, there have been a number of conventional global energy scenarios. Almost every one of them show

- a growing disparity in the energy consumption of industrialized and developing countries and
- virtually no improvement, even over several decades into the future, in the level of energy services for the populations of developing countries.

Attention must therefore be drawn to the work of Goldemberg, Johansson, Reddy and Williams in *Energy for a Sustainable World*[13]. They constructed what has come to be known as a *1 kW per capita scenario*[14] based on a thought experiment in which the following question was explored:

> if all developing countries achieved a level of energy services that obtained in Western Europe in the 1970s[15], and if they deployed the most efficient energy technologies available today, what would be the per capita energy consumption corresponding to this vastly improved standard of living?

The surprising result of this thought experiment was that *a mere 10% increase in the magnitude of energy would be required for the populations of developing countries to enjoy a standard of living as high as that which obtained in Western Europe in the 1970s provided that the best energy-efficient technologies available today are implemented*. In other words, under the conditions of this scenario, energy supplies need not become a constraint and dramatic increases in standards of living can be attained in the developing countries.

It follows that, if energy-efficient technologies are implemented to enable the populations of developing countries to realize a better standard of living, then it is likely that this standard of living is very likely to result in the low growth rates of the populations of developing countries characteristic of West European countries.

In addition to dramatic increases in standards of living for the populations of developing countries, the *1 kW per capita scenario* also led to a global energy scenario in which

- the total global energy requirement was only about 60% and 40% of that indicated by the IIASA Low and High projections, and
- there was, in stark contrast to all the other scenarios, a convergence of the per capita consumptions of the industrialized and developing countries.

4. Conclusions

By considering the energy-population nexus at the village micro-level and the global macro-level, it has been shown that the pattern of energy consumption can influence population growth by retarding or accelerating the demographic transition. Illustrative examples of energy strategies that can contribute to a reduction of the intensity of the population problem have been briefly described -- a biogas-based electricity-generation system at the village level and the *1 kW per capita scenario* at the global level. The essence of these energy interventions and alternative energy scenarios is the overriding emphasis on efficient energy technologies.

It is not the claim here that energy strategies alone will achieve a reduction in the desired number of births in a family and a decrease in the relative benefits of fertility. However, they are a necessary condition, if not sufficient. Unfortunately, they have been largely ignored as crucial interventions in the population problem. This lacuna must be corrected.

Notes and References

1… Though not germane to the subject of this paper, attention must be drawn to the growing view that population increases in the developing countries represents the most serious threat to the global atmosphere through the phenomenon of global warming. A counter view is that the patterns of energy consumption in the rich industrialized and poor developing countries, and the rich and the poor within developing countries, are such that the industrialized countries, and the rich within developing countries, have via their energy-intensive consumption patterns far greater per capita impact on the global atmosphere, and therefore the greater rates of population growth of the poor developing countries, and the poor within developing countries are far less relevant to global warming than the lower rates of population growth of the industrialized countries, and the rich within developing countries.

2… Coale, A.J., Recent Trends in Fertility in Less Developed Countries, Science, Vol. 221, 828-832, August 1983.

3… Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., Energy for a Sustainable World, pp 55-60, Wiley-Eastern Limited, New Delhi, 1988.

4… (a) ASTRA, Rural Energy Consumption Patterns -- A Field Study, Biomass, Vol. 2, No. 4, September 1982, 255-280.

(b) Ravinranath, N.H., Somasekhar, H.I., Ramesh, R., Reddy, Amala, Venkatram, K., and Reddy, A.K.N., The Design of a Rural Energy Centre for Pura Village, Part I: Its Present Pattern of Energy Consumption, Employment Expansion in Indian Agriculture, 1979, pp. 171-187, International Labour Office, Bangkok.

5… Transport has been included in agriculture because the only vehicles in Pura are bullock carts and these are used almost solely for agriculture- related activities such as carrying manure from backyard compost pits to the farms and produce from farms to households.

6… Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., Energy for a Sustainable World, Box 3.4, pp. 214-216, Wiley-Eastern Limited, New Delhi, 1988.

7… Pura uses about 217 tonnes of firewood per year, i.e., about 0.6 tonnes/day for the village, or 0.6 tonnes/year/capita.

8… Unlike some rural areas of India, dung cakes are not used as cooking fuel in the Pura region. In situations where agro-wastes (e.g., coconut husk) are not abundant, it appears that, if firewood is available within some convenient range (determined by the capacity of head-load transportation), dung-cakes are never burnt as fuel; instead dung is used as manure.

9… (a) Batliwala, Srilatha, Rural Energy Scarcity and Nutrition -- A New Perspective, Economic and Political Weekly, Vol. XVII, No. 9, February 27, 1982.

(b) Batliwala, Srilatha, Women's Access to Food, The Indian Journal of Social Work, Vol. XLVIII, No. 3, pp. 255-271, October 1987.

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12… (a) Reddy, A.K.N. and Balachandra, P., Chapter 7, pp. 66-75 in Power Generation through Renewable Sources of Energy, eds. B.R. Pai and M.S. Rama Prasad, (1991) Tata McGraw-Hill Publishing Company Limited, New Delhi.

(b) Rajabapaiah, P., Jayakumar, S. and Reddy, A.K.N., "Biogas Electricity -- The Pura Village Case Study", Chapter 19 in Fuels and Electricity from Renewable Sources of Energy, eds. Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H., Island Press (1993)

13… Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., Energy for a Sustainable World, Wiley-Eastern Limited, New Delhi, 1988.

14… Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., Basic Needs and much More with One Kilowatt per Capita, Ambio, Vol 14, No 4-5, 190-200 (1985).

15… The thought experiment was not intended to recommend "Western European" living standards as the goal for developing countries or to establish activity level targets for these countries to be achieved by some particular future date. The appropriate mix and levels of activities for the future in developing countries will have to be different to be consistent with the climate, culture and overall development goals. Rather, the purpose of the thought experiment was to show that it is possible, not only to meet basic human needs, but also to provide improvements in living standards that go far beyond the satisfaction of basic needs, without significant increases in per capita energy use. Thus energy supply availability per se need not be a fundamental constraint on development.

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