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Energy use and energy access in relation to poverty

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Abstract

This paper looks at how access and use of energy are related to poverty. Different approaches to how energy poverty might be measured are presented. One approach involves the estimation of basic energy needs of a household based on engineering calculations and certain normative assumptions. The second looks at poverty in relation to access to different energy sources. An alternative approach is then provided that combines the elements of access and consumption of energy in order to examine how these relate to the well being of households. Examining well being in terms of both these dimensions – access to clean and efficient energy sources; and sufficiency in terms of the quantity of energy consumed, could be an important complementary measure of poverty. The consumption dimension includes non-commercial consumption and thus includes self-produced and bartered products. The access dimension can serve as an indicator of the extent of market integration, or more specifically, as an indicator of the opportunity to join the modern market economy.

1   Introduction

Energy and poverty have figured in several recent policy documents and statements made by agencies such as the World Bank, United Nations Development Programme, World Energy Council and the UK's Department for International Development. A number of these reports were prepared in the build up to the Johannesburg 2002 World Summit on Sustainable Development, and all of them affirm that energy must be made a crucial part of all development and poverty alleviation projects and programmes [WEC 1999, WB 2000, UNDP 2000, DFID 2002]. As part of the Millennium Development Goals, the UN Commission for Sustainable Development 9th Session [CSD9 2002] also explicitly acknowledged that access to sustainable energy services is an essential element of sustainable development, stating that: "To implement the goal accepted by the international community to halve the proportion of people living on less than US$1 per day by 2015, access to affordable energy services is a prerequisite."

In this article we examine two questions. How can access to affordable energy services or some other measure of energy poverty be ascertained (sections 2 - 5 will deal with this), and is the resulting measure, perhaps, a useful additional indicator of poverty generally (this will be discussed in section 6 and some concusions drawn in section 7). Thus, in the latter two sections of the paper we add, in a sense, to the discussion on poverty measurement presented in the January 2003 special issue of the "Economic and Political Weekly".

2   Approaches to measuring energy poverty

One can distinguish three basic approaches to estimate the number of energy poor. The first of these strives at deriving an "energy poverty line" or "fuel poverty line" from a conventional income or expenditure poverty measure. This can be done by determining energy use as a function of income (or expenditure), and by calculating the average level of energy use corresponding to an amount of income or expenditure specified by the official income or expenditure poverty line (i.e. the level specified as the minimum amount needed to meet basic needs). In a recent paper, Foster et al. [2000] calculate a "fuel poverty line" using household survey data from Guatemala. They compute the average energy consumption of households whose overall per capita consumption expenditure level falls within a plus or minus 10% range of the official expenditure poverty line. This average energy consumption value is then assigned as the "fuel poverty line". In addition to deriving an "energy poverty line" as a function of the income poverty line, some authors have attempted to do the same by looking at energy use at the aggregate national level in relation to other broader measures of poverty such as the human development index (HDI) or physical quality of life index (PQLI) [Krugman & Goldemberg 1983]. While this approach is computationally fairly simple, it only provides a single energy or fuel poverty line, i.e. a single number that is basically a transformation of the monetary poverty line, and does not, by itself, add any new insight.

The second approach to measuring energy poverty, which is discussed in the following section, uses engineering type estimates for determining the direct energy required to satisfy basic needs. Finally, a number of authors define energy poverty in terms of access to energy services [see for instance Alam 1991, Mark 1998, Barnett 2000 for a discussion on how access to more efficient energy sources is related to an improvement in peoples level of well being]. Section 4 of the paper will deal with this issue, and Section 5 shows how engineering type calculations can be done for household groups that have access to different energy carriers.

3 Estimating basic energy needs

Early studies by Revelle [1976], Bravo [1979] cited in Krugman and Goldemberg [1983], Goldemberg et al. [1985, 1987], aimed at estimating basic energy needs on the basis of engineering type calculations. The results of calculations made by Goldemberg et al. estimated that the requirement of direct primary energy (a definition of various energy terms is included below) per time unit to satisfy basic needs is about 500 watt[1] per person. This kind of a calculation rests on a number of arbitrary assumptions regarding the type of energy consuming equipment (stove, light bulbs etc.), their sizes, efficiencies and intensity of use. In addition, the approach requires as a first normative step defining a set of basic needs. This is a problematic endevour. Basic needs vary with climate, region, period in time, age and sex. More importantly, there is not a single level, but a hierarchy of basic needs.

A similar engineering approach for estimating the basic energy needs for cooking, lighting and heating was adopted by planning agencies in India in fixing 'norms' that where then used while forecasting and evaluating energy demand, especially in rural areas. The Advisory Board on Energy in its 1984 report on energy demand modelling for India [ABE 1984] assumed that about 30 watt of useful energy is needed per capita to meet cooking energy needs. Similarly about 1.5 watt of useful energy per capita is required to meet space heating needs and the same amount again, 1.5 watt of useful energy per capita, to meet lighting needs. These values are normative in the sense that they are calculated on the basis of various assumptions regarding what is considered as the basic minimum needed to meet human needs. Thus a total of some 33 watt of useful energy per capita was assumed by ABE to be required at the household level to meet the three basic direct energy services, cooking, lighting and space heating. This converts to almost 250 watt of primary energy, which is about half of Goldemberg's estimate, which is based on his own stipulations of basic needs.

Energy consumption can be measured at various levels of the energy supply chain. As the choice of the level influences the explanatory power of the energy poverty measurement, let us make a slight digression to recapitulate the definition of these levels.

1. Primary energy is the energy contained in energy carriers sold by firms, or division of firms, of the energy extraction sector: coal sold by coal mining firms, crude oil sold by oil extracting companies or, trunks of wood sold by logging firms. In addition, wood and other biomass collected by householders directly from the environment, before being transported, stored and dried, can also be termed primary energy.

2. End-use energy is the energy sold to a household or firm that is not part of the energy industry, i.e. that buys the energy for its own use and not for sale to a third party (be it in the same form or not). Kerosene in a 10-litre canister, electricity at 220 Volts supplied to the electricity counter of a residence and collected wood, ready to use, are examples of energy at the end-use level.

3. What householders are looking for is not so much fuel or electricity, but rather heat supplied to a room or to a cooking pot or the mechanical energy applied to air for air

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1 A watt is a measure for (physical) power, i.e. energy per unit time. Following José Goldemberg, the most prominent and one of the first to write about energy and poverty, we will use watt as the unit to measure energy per unit time. Energy use is almost always expressed as energy per unit time, but instead of using the unit for power, one usually uses explicitly an energy unit per a time unit, such as GJ per year. According to Goldemberg (1990), 1000 watt per capita is the power required to satisfy basic human needs: 500 watt directly in the form of fuels and electricity and 500 watt indirectly as a result of consuming other goods and services which are necessary to satisfy basic needs and that require energy inputs for their production.

circulation or to water to be lifted to a tank. They do not only have to acquire end-use energy, but also equipment, such as heaters, stoves, pumps and lamps, transforming end-use energy into heat, mechanical drive and light at the desired location and time. This latter energy is called useful energy.

4. But finally, the direct demand is on energy services: a cooked meal, a well-lit reading corner, being transported from A to B, a cool room, a hot shower etc. The problem for the analyst is, that these so-called energy services cannot be measured in energy units, that they require many other things than energy carriers and that there is no way of distinguishing energy services from other services and products. All products and services take some energy to produce, i.e. contain some embodied energy, and are, therefore, energy services in some sense.

Although the energy services themselves cannot be measured in energy units, it is possible to measure energy requirements for energy services. Of course, households do not buy energy at the level of primary energy, but it is possible to express their energy needs at the primary energy level; by calculating how much primary energy it took to produce the purchased end-use energy, which in turn provided the "demanded" energy services. Because the provision of energy services requires also stoves, lamps, heaters, insulated walls, etc. two types of primary energy flows are necessary for any energy service:

- Direct energy, i.e. the primary energy it takes to produce the purchased end-use energy, (commercial and non-commercial energy collected directly from the environment) and;

- Indirect energy, i.e. the primary energy it takes to produce equipment (stoves, lamps, heaters, insulated walls, etc) necessary for the provision of energy services. Indirect energy is sometimes also called embodied or grey energy.

In absence of the direct measurability of energy services, a promising option is to measure consumption at the level of useful energy, particularly in the context of measuring well being. It is not the consumer who's purchased energy requires large quantities of primary energy, nor the consumer who purchases large amounts of end-use energy, who is well off, but the consumer who enjoys all the energy services she or he desires. Measuring useful energy gives us a better idea of the energy services enjoyed by a consumer rather than measuring primary energy or end-use energy. The quantity of end-use energy is strongly dependant on the efficiency of the equipment in which it is transformed into useful energy and the quantity of primary energy is, in addition, dependant on the efficiency of the energy supply chain. For the case of a country like India, where a very large proportion of the direct energy use is still non-commercial biomass energy, measuring energy in useful terms is particularly appropriate because if we add energies at the level of primary energy, the energy content of biomass is high compared to its utility. This is due to the fact that for cooking, the end-use energy conversion efficiency of most non-commercial energy carriers is very low.

Having said this, we have to add a note of caution here. In contrast to primary energy, for which there are well-established rules of adding-up different energy carriers, such as crude oil, coal and wood, analysing useful energy makes sense only, when one compares various ways of providing one kind of useful energy (for e.g. heat, mechanical drive, light, chemical energy) for one specific energy service, such as heat supplied to a cooking pot. Adding-up "useful energy" employed for different energy services is more problematic. For instance, "heat supplied to a cooking pot" and "the energy of light coming from a light bulb", are two energy flows of very different physical form and utility, which required different cost (technically, resource wise and economically) to produce. Adding them up often produces irrelevant results. In what follows we will add-up useful energy, keeping this note of caution in mind and noting, that in the case of

measuring energy poverty, cooking is such a dominant energy service, that we are not overstretching the applicability of useful energy.

Table 1: Energy requirements for energy services demanded by households

Energy Services	Average power per household (in W)		
	useful energy	end-use energy	primary energy
1 Lighting electric bulb (60W)[a]	10	13	45
2 Lighting ~1 kerosene lamp[b]	0.01	19	22
3 kerosene pressure 1 lamp[b]	0.5	76	90
4 back-up kerosene (lightning)[b]	0.01	11	13
5 Cooking tradi.biomass 1 meal daily[c]	55	393	401
6 Cooking kerosene stove 1 meal daily[c]	55	123	144
7 Cooking LPG stove 1 meal daily[c]	56	93	109
8 Space cooling 1 room[d]	292	146	530
9 warm water (fuelwood; 5 litres/day)[c]	7	52	53
10 warm water (kerosene; 5 litres/day)[c]	7	16	19
11 electric geyser (10 litres/day)[c]	15	22	82
12 Refrigerator small[d]	40	20	72
13 Refrigerator large[d]	75	37	136
14 washing machine[d]	10	14	52
15 household devices[e]	1	2.5	9
16 Radio[e]	3	5.8	21
17 TV (Black & White or Color)[e]	7	14	52
18 Computer[e]	8	17	61
19 Car (per 10km/day)[f]	66	356	456
20 Scooter per 5km/day)[i]	13	73	91

Notes:
a) *Source* : http://www.energieinfo.de/eglossar/node204.html
For electricity we assumed a conversion factor of 0.75 for going from end-use to useful energy.
b) *Source* :Plas R. & A.B. de Graaff (1988)
c) *Source* : Reddy (2003), Ravindranath & Hall (1995), OTA (1991) and Gupta & Rao (1979)
d) *Source* : http://www.physik.uni-muenchen.de/didaktik/U_materialien/leifiphysik/web_ph10/
e) *Source* : Cremer et al. (2003)
f) *Source* : http://www.energieinfo.de/eglossar/node129.html

The main energy services that are in demand in households and their primary and useful energy requirements are reported in Table 1. The third column gives some engineering estimates for the direct energy requirements, both commercial and non-commercial, at the level of end-use to provide these energy services. These estimates are converted into primary energy and useful energy[2] by assuming certain efficiencies of the end-use equipments and of

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[2] For electricity we assumed a conversion factor of 0.75 for converting from end-use to useful energy while estimating household energy consumption from the NSSO survey data. This is correct for cooking and some other appliances. For air conditioning it is too low. For lighting, the customary conversion factor is 0.1 or even 0.025, depending on the efficiency of the light bulb. This is the result of regarding the light waves themselves as useful energy. However, we have to choose here one factor for all electric energy services. To be precise, by choosing 0.75 for all electric energy services, we define in this article "useful energy" to be synonymous with

the energy supply and conversion chain. The efficiencies of stoves are strongly dependant on the household size. The efficiencies assumed for cooking refer to households of average size.

Depending on what is considered the basic minimum in terms of energy services that a household needs, one can then use this table to calculate the minimum energy requirements necessary to meet these basic needs in terms of either useful or primary energy.

4 Access to energy services

Physical access to energy and to energy using end-use equipment is a prerequisite for access to energy services. However, physical access alone does not ensure that the household does in fact have access to energy services. In addition to physical access, real access to energy services can be limited by the purchasing power of the household, the cost of energy and cost of energy using equipment.

Figure 1: Distribution of households by type of fuel used
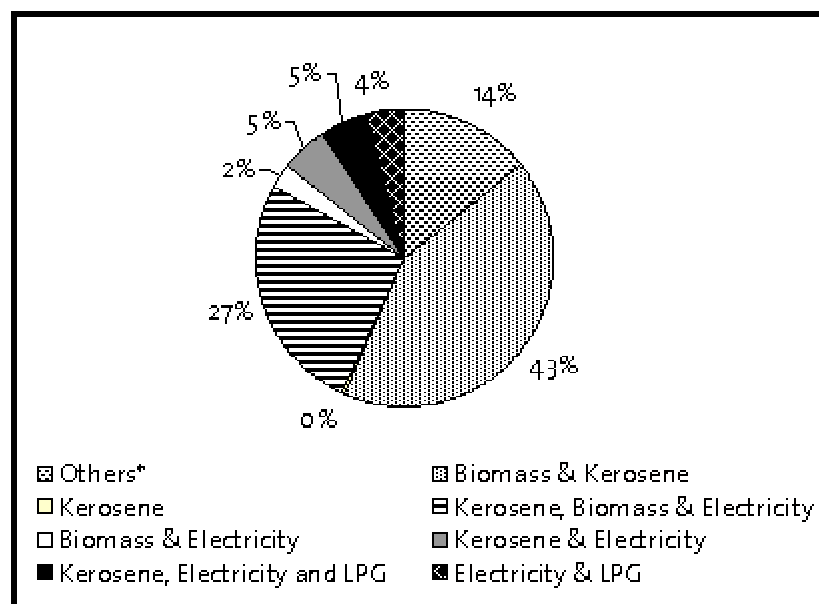
Note: * The category 'Others' includes those households where the data for fuel use from the NSSO survey data was inconsistent. In other words, where values for quantity of fuel where missing, even though the household reported the use of certain fuels in another part of the questionnaire.

In India, as in many other developing countries, access to energy sources differs significantly between rural and urban areas, with rural areas often lacking access to more efficient sources of energy and well functioning markets for energy and energy end-use equipment. While it is difficult to find data that indicates whether households have access to a particular source of energy or not and the quality of the energy they receive, the household expenditure survey carried out by the National Sample Survey Organisation (NSSO), does provide data on actual use of different energy sources and this might be used as a proxy for access. Using data from

"useful energy for cooking" and, we have furthermore, the advantage of not rendering the useful energy for electric lighting irrelevant, as is done by applying the very low conversion factors.

the 1993-94 NSS household expenditure survey (Round 50) [NSSO 1997], one can observe that most households in India use on average, at least two different types of fuels., In other words, multiple fuel use is the norm for most households.

In Figure 1 we present the distribution of households in India according to the type of energy used based on the data from the NSS data for the year 1993-94 (Round 50). The majority (about 43%) of the households use a combination of biomass and kerosene to meet their direct energy needs, and about a third of all households use 3 or more fuels. In contrast, the number of households dependent on a single energy type for meeting direct energy needs are very few.

What determines the choice of fuels used by a particular household has been the subject of much research. The traditional view on fuel switching in the household sector of developing countries has been that households gradually ascend an "energy ladder" and that there is a simple progression from relatively inefficient fuels and energy end-use equipment to more efficient fuels, electricity and equipment, with increasing income levels and urbanisation [Leach, 1992, Sathaye & Tyler, 1991, Smith et al., 1994, Reddy & Reddy 1994]. However, recent literature on household energy use in developing countries shows that, in fact, the switch from inefficient to more efficient fuels and equipment is not a linear or unidirectional process as suggested by the simple energy ladder theory [Davis 1998, Masera et al. 2000 and Barnett 2000]. The data presented here, too, shows that households in India tend to use multiple fuels, which correspond to a vector of energy services. Complete switching, where one fuel totally substitutes for another, is rare. The reasons for multiple fuel use are varied and not dependent on economic factors alone, although the affordability or cost of the energy service also has an important bearing on the household's choice. In some cases, households choose to use more than one fuel because they want to increase the security of supply. In other cases, the choice is dependent on cultural, social or taste preferences.

The affordability of the different energy types for households depends on the market prices of the energy sources themselves, and also on efficiencies and costs of appliances needed for employing the specific energy types. In some cases, while there may not be any monetary value or price associated with certain non-commercial fuels, such as wood or dung, there is still an opportunity cost in terms of the value of the time spent in collecting the fuelwood. However, where available, fuelwood continues to remain the preferred energy source among the poor because it does not have a monetary price attached to it and can be collected from nearby forests, common lands or private lands individually. In addition, the capital cost of the stove required to burn the wood is almost negligible, especially for the simplest (and also most inefficient) primitive three-stone stove. However, there is often a market price for fuelwood in urban areas. In addition, since the efficiency of this fuel type is so low, if one compares the price per unit of useful energy used, then the cost advantage of fuelwood over other energy types is wiped out. In fact, it is often the case that poor households generally spend more money buying, or more time collecting, each unit of energy they consume compared to wealthier households [Dutt & Ravindranath, 1993]. Table 2 provides a comparison of households on the basis of energy types, expenditure on energy and price per unit end-use and useful energy. In general, one sees from the table that, in both rural and urban areas, households that are dependent on fewer energy carriers tend to pay more in terms of the price per unit useful energy than those that diversify use to many fuels. In addition, households that are dependent on combinations of fuels that include less efficient energy carriers pay more per unit of useful energy than those that use more efficient energy forms.

In addition to the price of energy, the cost of the energy end-use equipment also influences the choice of energy carrier used by the household. A recent paper by Reddy [2003] compares the annualised life cycle cost, estimated on the basis of the capital cost of end-use equipment, its life span, operating cost and the energy carrier price, for different household energy technologies in India. The paper shows that when comparing the total annualised cost fuelwood remains an attractive option for households as compared to LPG, because of the high

capital cost of LPG stoves, however, a switch to biogas results in the highest cost savings and also affords other benefits in terms of improved efficiency and indoor air quality.

Table 2: Fuel costs per unit end-use and useful energy

Category of Users	Energy Expenditure (Rs. per year)	Energy expenditure as a percentage of total household expenditure (%)	Price per unit end-use energy (Rs per Kwh)	Price per unit useful energy (Rs per Kwh)
RURAL				
Biomass	1227	10.1	0.09	0.46
Biomass & Kerosene	1129	8.8	0.07	0.33
Biomass & Electricity	1477	8.6	0.08	0.31
Biomass, Kerosene & Electricity	1435	8.2	0.08	0.28
Kerosene & LPG	1670	6.1	0.19	0.37
Kerosene, LPG & Electricity	2105	7.1	0.18	0.31
Electricity & LPG	1896	6.4	0.20	0.33
URBAN				
Biomass	1328	9.4	0.14	0.68
Biomass & Kerosene	1185	8.8	0.08	0.37
Biomass & Electricity	1261	8.4	0.09	0.34
Biomass, Kerosene & Electricity	1595	8.7	0.09	0.33
Kerosene & LPG	2145	6.6	0.22	0.43
Kerosene, LPG & Electricity	2427	7.5	0.18	0.32
Electricity & LPG	2528	7.1	0.21	0.33

5 The energy use - access matrix

In the preceding two sections, we presented two alternative approaches to looking at energy use and access in relation to poverty. In this section, we combine these two approaches and look at household groups that are classified both by their access to different energy sources and their levels of energy use.

Table 3 shows both how many households in India have access to the three main combinations of end-use energy and consume an amount that lies in the four intervals: 0 to 15, 15 to 30, 30 to 60 and >60 watt/capita of useful energy. What energy services might be available in these intervals of useful energy is also indicated. The basis for the latter description is the information presented in Table 1. These intervals for level of energy use have been constructed and choosen to reflect a progressive improvement in the level of energy services that they can afford. Thus, for instance, the lowest energy consumption category, indicates a level of energy services that might be associated with abject poverty, while the highest reflects a level of energy services that would afford a comfortable level of well being. However, at the same time, it must be kept in mind that the types of energy services associated with each of these individual levels of energy consumption, do differ also with the types of energy sources used. So, households that lie in the highest energy consuming category but use only biomass and kerosene, would be able to enjoy mainly energy services associated with well cooked meals and some lighting, whereas those that have access to eleclticity could enjoy the added benefits of energy services associated with the use of electrical equipement and appliances.

Table 3: Grouping of five-member households according to energy access and levels of useful energy consumption

Useful energy *Examples of energy services, which may be available in the given intervals of useful energy* Access	Less than 15 watt/cap *Less than one warm meal per day, a kerosene lamp, possibly a little hot water*	15 to 30 watt/cap *One to two warm meals per day (for farmers and manual labourers below basic need), a few kerosene lamps or one electric bulb, some hot water*	30 to 60 watt/cap *Two warm meals per day (group without electricity has "farmers portions"), hot water and lighting. Some small electric appliances (TV, telephone, fridge) for groups with electricity. Possibly a scooter*	More than 60 watt/cap *Two or more warm meals per day, hot water, lighting, some space heating and – in case of groups with electricity, possibly some space cooling, as well as other electric appliances. Possibly a scooter or a car*
Biomass and kerosene	8.1% of 5-memb.-HH pop. 12% tap water 63% illiterate 93% rural HH-land holding: 0.55 ha expend./cap: 1101 Rs./m primary energy/cap: direct 46 watt, total* 151 watt	26.2% of 5-memb.-HH pop. 16% tap water 58% illiterate 92% rural HH-land holding: 0.65 ha expend./cap: 1150 Rs./m primary energy/cap: direct 100 watt, total 211 watt	11.1% of 5-memb.-HH pop. 14% tap water 54% illiterate 95% rural HH-land holding: 0.88 ha expend./cap: 1381 Rs./m primary energy/cap: direct 182 watt, total 309 watt	1.3% of 5-memb.-HH pop. 14% tap water 49% illiterate 95% rural HH-land holding: 1.15 ha expend./cap: 1466 Rs./m primary energy/cap: direct 405 watt, total 539 watt
Electricity, biomass and/or kerosene	3.8% of 5-memb.-HH pop. 35% tap water 37% illiterate 67% rural HH-land holding: 0.75 ha expend./cap: 1493 Rs./m primary energy/cap: direct 51 watt, total 178 watt	17.8% of 5-memb.-HH pop. 44% tap water 35% illiterate 65% rural HH-land holding: 0.72 ha expend./cap: 1536 Rs./m primary energy/cap: direct 100 watt, total 232 watt	17.1% of 5-memb.-HH pop. 46% tap water 30% illiterate 69% rural HH-land holding: 1.0 ha expend./cap: 1873 Rs./m primary energy/cap: direct 174 watt, total 335 watt	2.1% of 5-memb.-HH pop. 46% tap water 31% illiterate 81% rural HH-land holding: 1.5 ha expend./cap: 2359 Rs./m primary energy/cap: direct 385 watt, total 587 watt
LPG, electricity, and possibly kerosene	Less than 0.1% of the 5-member-HH population	1.9% of 5-memb.-HH pop. 81% tap water 10% illiterate 14% rural HH-land holding: 0.27 ha expend./cap: 2590 Rs./m primary energy/cap: direct 76 watt, total 265 watt	8.1% of 5-memb.-HH pop. 81% tap water 4% illiterate 15% rural HH-land holding: 0.24 ha expend./cap: 2904 Rs./m primary energy/cap: direct 139 watt, total 368 watt	2.3% of 5-memb.-HH pop. 87% tap water 2% illiterate 12% rural HH-land holding: 0.39 ha expend./cap: 4764 Rs./m primary energy/cap: direct 311 watt, total 653 watt

Note: *Total primary energy (direct and indirect) per capita calculated according to the methodology described in Pachauri and Spreng [2002] and Pachauri [2002].

The 3x4-matrix serves as an illustration, larger matrixes with smaller intervals, corresponding to more detailed descriptions of available energy services, and with more detailed groups regarding access can be constructed easily. Also, it is possible to construct similar matrices for individual States or for households with particular socio-economic characteristics. A note of caution is needed here since specific energy use depends strongly on household size. As the engineering estimates of energy requirements for energy services used in this paper are in relation to the typical or average size of household, the simplest way of dealing with this issue of houshold scale and composition differences is to look at households of an average size only. Thus, in Table 3 we present results only for a sub-sample of Indian households corresponding to those whose number of household members is 5 (this corresponds to the median size for India and approximately 20% of the total population). Ideally it is necessary to look separately at groups of households of a particular size, or to convert the energy requirements of all the households into a norm size. This is a difficult undertaking and might be done as part of future research[3]. It also needs to be mentioned that there are issues regarding the quality of the NSS data[4] that need to be considered. In general, estimates of physical energy consumption from the sample data are underestimates. It is also likely that the cut off values for useful energy intervals constructed from the engineering calculations are underestimates, since in practice the different end-use devices might be left running beyond the time of use assumed and the efficiencies of –often not well functioning equipement –might be lower than that of the equipment measured.

Looking at the characterisitics of households presented in Table 3, one observes that not only some of the important infrastructure characteristics correlate strongly with the energy access, but also literacy and other socio-economic characteristics. In row one of the table that represents households having access to biomass and kerosene, it can be seen that a shift rightward to higher levels of energy use is almost uncorrelated with improvments in the level of some of the basic infrastructural characteristics of the households. Thus, for instance, we observe that biomass and kerosene users in the highest energy use category do not differ significantly from those in the lowest energy use category in terms of literacy or access to tap water systems. However, even for the lowest energy use category, access to electricity (a shift downward in the table from biomass and kerosene users to electricity, biomass and/or kerosene users) correlates with a significant improvement in the indicators relating to literacy and access to tap water. At the same time though, there are significant differences in the level of well being of households falling in the biomass and kerosene category as one moves rightward from those who have very low levels of energy use to those who use more. These differences are reflected in the average level of energy services that these households can consume and the land holdings they own. The corresponding increase in household expenditure across these energy use categories is more moderate however, and reflects the lack of market integration of these households, as most of their consumption is not bought at a market place and might be more in the nature of production for self-consumption or barter exchanges.

One also observes, as might be expected, that the level of direct primary energy needed to provide the same level of energy services is lower for households that have access to more

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[3] For the same NSS round as the one we are using Meenakshi & Ray [2002] investigate how household size and composition affects monetary consumption. As an exercise we converted household energy consumption data to useful energy per capita by applying the correction factors determined by Meenakshi and Ray. The results of this exercise show that, in percentage terms, the distribution of households using data from the full sample corrected for household size and composition effects is virtually the same as the one for five person-households only presented in Table 3.

[4] A number of papers in the literature deal with the issue of quality of estimates of private consumption expenditure from the NSS data. See for instance Sundaram and Tendulkar [2003].

efficient energy forms as compared to those primarily relying on biomass energy. Thus, if one compares the average direct primary energy requirements of households in the higher energy consuming categories (colomns 3 and 4 of the table) for groups with differing access to energy sources, one observes that the average value for biomass and kerosene users is higher than the value for electricity, biomass and/or kerosene users, whereas average direct energy use of the LPG and electricity users is the lowest of all three access categories. In contrast to the values for direct energy, total (direct and indirect) primary energy use increases consistently both across access groups and energy consumption categories. This implies that the indirect energy requirements associated with the consumption of other non-energy goods and services rise in per capita terms both with better access to more efficient energy forms and with increased use of direct energy.

The approach presented in Table 3 also allows one to draw any number of poverty lines based on differing assumptions regarding what constitutes basic minimum energy needs. For instance, the tripple shaded line in the table, is one such poverty line that could be drawn. This line provides a border, which is defined both by the amount of energy consumption as well as the access to different energy carriers, and both of these elements in turn define the extent of energy services available to the household. According to this energy poverty line, about 38% of the 5-member household population falls in the poor category, where "poor" is defined largely by our choice of the energy poverty line and refers to those households that get less than two cooked meals a day. The reader is welcome to draw hers/his own poverty line across the matrix presented in Table 3.

Finally, the table also reveals some urban-rural differences in terms of access to energy sources. Among biomass and kerosene users, almost 95% on average live in rural areas, whereas on average, less than 15% of electricity and LPG users reside in rural areas.

6   Can energy serve as a useful measure of poverty?

In the preceding sections we presented various ways of measuring poverty in energy terms. In this section, we point to some further motivations for the approach presented above. We do not claim to have found the one and only measure for poverty, but we believe energy to be one highly useful measure among others, particularly as an important complement to monetary measures such as consumption and income[5] ,as well as, to composite indices such as the human development index (HDI). In what follows we present some arguments in favour of energy as a measure of poverty and some suggestions on what is a practical means of measuring energy poverty.

Crossing the money boundary

The conventional approach to measuring well being or poverty, in India as is the case in the rest of the world, is one that equates poverty with material deprivation and defines the poor in terms of incomes or levels of consumption. Or in other words, poverty is conceptualised in material terms as not having a sufficient level of income to pay for the consumption of

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[5] We would like to note, that we take distance from attempts to claim energy or any other physical measure to be a better measure than money for the value of things. The Technocracy movement in the US (http://www.technocracyinc.org) is campaigning since the 1920's for the introduction of energy, in form of energy debit cards, as exchange currency. Howard Odum [1996] proposed "emergy", a physical quantity closely related to energy [embodied solar energy], to be the true measure of value. These quantities have the apparent appeal of being objective. In fact, however, they reflect the valuation of a single individual or of a small group of individuals. Monetary valuation is more democratic; it reflects, at least in principle, the assessment of all participants in the market.

adequate amounts of food, water, clothing, shelter, sanitation, health care and education. The Planning Commission in India, for example, has for many years defined poverty in terms of the level of per-capita consumer expenditure sufficient to provide an average daily intake of 2400 calories per person in rural areas and 2100 calories per person in urban areas, plus a minimal allocation for basic non-food items.

To focus on poverty measures solely in monetary terms of income or consumption (total or food) reflects a static concept, offering only a limited picture of household well being. The conventional measures of income or expenditure poverty provide information only on the percentage of population falling below an officially specified minimum level, without providing more in-depth information regarding why these households are poor or the dynamics of movements of households in and out of poverty, their risks and vulnerabilities.

In addition to the fact that conventional monetary measures of poverty are static, they also at times provide an incomplete view of poverty and at times could even be misleading. In cases, where a household is well-off and self-sufficient, but is not well integrated into the market economy, it may be mistaken as poor when the monetary value of its market transactions is the basis for measuring poverty. This is not a minor problem. The loss of autarchy in the provision of basic needs for a large fraction of households, during a given period of development in a given region, may be mistaken for a positive trend, even if it is not. With a moderate increase of trade and monetary exchange, poverty, measured in monetary terms, will seemingly decrease, even if during the same time an important reduction in the provision of basic needs takes place, which occurred earlier through barter exchange and without resort to monetary markets.

Including non-commercial energy in our analysis is consistent with our analytic approach situated, in terms of disciplines, between engineering and economics. It has the welcome effect of including the consumption of non-monetised goods. A well-off autarchic household will be a large consumer of non-commercial energy. A massive shift on the macro-level away from a barter economy and self sufficiency, with but a small increase in market economy, will not be mistaken to be an increase in well-being.

There are, however, two problems with the inclusion of non-commercial energy in the analysis:

- The available data for non-monetary exchanges of goods is not recorded with the same accuracy as monetary exchanges. The latter are recorded by vendors and buyers, often are then registered in formalised balance sheets of traders and banks as well as on tax forms. For wood and other biomass collected in nature, nobody is obliged or much interested in recording the amounts. The data we have are estimates or records of surveys. Again the survey results depend on the good will and memory of the respondents, who do not have the possibility of looking-up any bills or bank statements.

- We actually would have liked to include data on animal traction, an important source of mechanical drive. But we did not find data of sufficient quality and detail (a distinction of traction for agricultural purposes, such as tilling and pumping, for transport in the productive sectors, and for transport in the household sector, would have been the minimum requirement) to make it worth including them.

Entering the energy sphere

Three basic approaches to measuring energy poverty were presented in this paper. The first of these, which uses the official income or expenditure line as the basis of calculating the energy poverty line, while fairly easy to apply, provides us with no additional insights on poverty other than just an average energy use value that corresponds to the official monetary poverty line. The second approach which uses engineering type calculations to determine the energy requirements for a normatively defined set of basic needs and by making assumptions

regarding the types of energy used, and the sizes, efficiencies and intensities of use for end-use energy equipment, does help determine the energy needs corresponding to a vector of energy services, rather than just a single average value. In this sense, it maybe argued that this is a more robust measure than the first of the measures discussed, as it is able to better capture some aspects of the multidimensionality and diversity of the poor. In addition, the approach has the added advantage that it allows for distinguishing between the basic energy needs of rural and urban households and those residing in different climatic regions.

The third approach, is measuring poverty in terms of access to energy services. This, it might be argued, is an important complement to a consumption based measure of poverty[6]. For instance, whether a household chooses to use a number of different electrical equipments or not is a matter of choice, what is important however, is that the household has that choice to make and for that the households must have access, i.e. physical access to electricity (the electrical grid and a home connection), physical access to markets where they can buy electrical equipment, and the purchasing power to be able to buy the equipment and the electricity at a competitive price. Thus, what distinguishes a poor household from a better off one is also the wider range of choice in terms of which fuels to use (more efficient, more convenient, less polluting), which equipment and appliances to buy (coolers and fans and fridges to attain comfortable indoor temperatures to live in when it's more than 40 degrees C. outdoors) and in addition, a greater choice in terms of varieties, qualities and types of all other goods and services to buy (pukka house, better clothes, better tasting and more nutritious and diverse diet, etc).

Finding data on access to energy services can be quite difficult. One needs data not only on the physical access to different energy types, but also data on whether the household has access to markets that sell different energy using equipments and information on the purchasing power of the household, as well as the market prices of the fuels and equipments. As shown in this paper, we use data on actual consumption of different energy types as a proxy to measure access to energy services. The implicit assumption we make here is that if a certain household uses a particular fuel then it must also have access to the end-use equipment required to convert that fuel and meet some demand for energy service by the household and vice versa, i.e. if there is access (physical, to equipments and markets) then some amount of that energy carrier will be consumed by that household. However, in most cases this is a reasonable assumption to be made.

The approaches presented in this paper admittedly require certain assumptions, simplifications and approximations to be made. However, we feel that a combination of access to energy carriers and a list of energy services consumed for different groups of households can provide, so to speak, a stereoscopic view on poverty, which may serve as a useful, additional and robust measure of poverty. Some of the main advantages of such an approach, as we have already shown, are that we do not only measure consumption, but also, in some sense, capability. This approach also takes into account to some extent the non-monetised part of household transactions (non-commercial energy), and it captures to a greater extent the diversity of the poor by looking at different combinations of fuels/equipments that might provide the same or

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[6] This is in line with Sen's argument in favour of the capability approach for measuring poverty. In Sen's view the "standard of living" is not a matter directly of income, commodities or utilities. What is valued intrinsically are people's "capabilities" to function, and "poverty" is interpreted as lack of capability. The capability approach thus focuses on an individual's capacity to live a healthy life, free of avoidable morbidity, having adequate nourishment, being informed and knowledgeable, being capable of reproduction, enjoying personal security, and being able to freely and actively participate in society. Material resources at some level are generally necessary for some of these activities, but they are not sufficient. Measures which focus on capability poverty thus incorporate access to public services, assets and employment, as well as money metric measures which reflect the ability to 'purchase' food, clothing and shelter [Sen 1985, 1993].

different energy services, and it allows for defining any number of different normative energy poverty lines rather than a single static one. Such a measure could also serve as an indicator of the extent of market integration, or more specifically, as an indicator of the opportunity to join the modern market economy.

7 Conclusions

So how might one relate access and use of energy to poverty? As we have shown in this paper, the access to different energy sources and levels of energy consumed are important dimensions that need to be analysed in order to make any inferences regarding the level of well being of a household. In section 3 of the paper, we presented one approach where basic energy needs of a household are estimated based on engineering estimates and certain normative assumptions regarding what one considers to be basic minimum needs. While this approach is useful to some extent in order to identify those who might not be able to afford even the basic minimum energy services, it alone does not provide sufficient information. This is because the level of energy services that can be enjoyed for the same level of energy use can differ widely across households that have access to energy sources of differing efficiencies. Thus, in section 4, we present an alternative approach which looks at poverty in relation to access to different energy sources. This is a crucial dimension of any well being analysis since access to more efficient energy sources not only implies a higher level of energy services associated with a lower level of energy use, but also affords many other benefits such as improved indoor air quality, more time for productive or recreational activities, time that is freed up from collecting biomass energy, etc. However, at the same time, access alone does not provide sufficient information for one to draw conclusions regarding well being. For instance, some households that use only biomass and other less efficient energy sources, but use a sufficient quantity of these sources might be considered better off than others that have access to more efficient energy sources but can not consume adequate amounts of energy. Therefore, in section 5 of the paper, we present an alternative approach that combines the elements of access and consumption of energy in order to view households and to relate it to their level of well being. In this case, it is possible to look at poverty in terms of both dimensions – access to clean and efficient energy sources; and sufficiency in terms of the quantity of energy consumed. Then, it is evident that to improve the well being of the poor, two elements are needed, to improve access to efficient energy sources; and to ensure that they get an adequate quantity of energy by making it affordable.

As a final comment, we point out some of the limitations of the analysis presented in this paper. In what is presented above, we do not take into account regional differences in energy needs on account of climatic variations. These variations can be quite substantial, especially heating energy needs can be higher in hilly and mountainous regions. In addition, there might be diversity in energy use patterns due to local cultural and taste factors. However, the approach presented here could in principle be refined to produce estimates separately for households residing in different States, climatic regions, etc.

To conclude, we mention briefly a policy issue which, while not directly analysed in the work presented here, does deserve a comment. Subsidising energy to the household and agricultural sectors of the economy have long been a policy followed by the government with the view to make energy affordable to the poorest sections of society. However, the data presented here provides renewed evidence of the fact that energy subsidies, particulary those in the form of low tariffs for electricity, are essentially appropriated by that part of the population which is less poor. This is because, if one observes the data for access to different energy sources, it is clear that the poorest households do not have access to electricity. An energy policy that takes poverty reduction seriously must subsidise energy infrastructure expansion to poor areas rather than the energy itself. This might even be financed by a tax on energy use.

References

Advisory Board on Energy (ABE) (1985): 'Towards a Perspective on Energy Demand and Supply in India in 2004-05', Report of the Advisory Board on Energy, Government of India, New Delhi.

Alam, M.S., et al. (1991): 'A Model for the Quality of Life as a Function of Electrical Energy Consumption', *Energy*, Vol 16, No 4, pp 739-745.

Barnett, Andrew (2000): 'Energy and the Fight against Poverty', Department for International Development (Dfid), Livelihood sector report, UK.

Cremer, C., Aebischer, B., Huser, A. et al. (2003): 'Der Einfluss moderner Gerätegenerationen der Informations- und Kommunikationstechnik auf den Energieverbrauch in Deutschland bis zum Jahr 2010 - Möglichkeiten zur Erhöhung der Energieeffizienz und der Energieeinsparung in diesen Bereichen', Studie von FhG-ISI und CEPE im Auftrag des Bundesministeriums für Wirtschaft und Arbeit, Karlsruhe/Zürich.

Commission on Sustainable Development (CSD 9) (2002): 'Ninth session, Agenda Item 4, Decision', Energy for Sustainable Development, Section 6.22, United Nations.

Davis, Mark (1998): 'Rural Household Energy Consumption: The Effects of Access to Electricity – Evidence from South Africa', *Energy Policy*, Vol 26, No 3, pp 207-217.

Department for International Development (DFID) (2002): 'Energy for the Poor', Consultation Document, London, UK.

Dutt, G. and Ravindranath, N. (1993): 'Bioenergy: Direct applications in cooking', in: Johansson, Thomas B., Henry Kelly, Amulya K.N. Reddy and Robert H. Williams (eds.), *Renewable Energy: Sources for Fuels and Electricity*, pp 653-698, Island Press, Washington DC.

Foster V., Jean-Philippe Tre, and Quentin Wodon, (2000): 'Energy prices, energy efficiency, and fuel poverty', Latin America and Caribbean Regional Studies Program, The World Bank, Washington, D.C.

Goldemberg J., (1990): 'One kilowatt per capita', *Bulletin of the Atomic Scientists*, Vol 46 No 1.

Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams (1985): 'Basic needs and much more with one kilowatt per capita', *Ambio,* Vol 14, No (4-5), pp 190-200.

Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams (1987): *Energy for a Sustainable World*, Publishers - Wiley-Eastern Limited, New Delhi.

Gupta C.L., Rao K.U. (1979): 'Domestic energy consumption in India (Pondicherry Region)', *Energy*, Vol 5, pp 1213-1222.

Krugman, H. and Goldemberg, J. (1983): 'The energy cost of satisfying basic human needs', *Technological Forecasting and Social Change*, Vol 24, pp 45-60.

Leach G. (1992): 'The Energy Transition', *Energy Policy*, Vol 20, No 2, pp 116-123.

Masera, O., Saatkamp, Barbara and Kammen, Daniel (2000): 'From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model', *World Development*, Vol 28, No 12, pp 2083-2103.

Meenakshi, J.V., and Ranjan Ray (2002): 'Impact of household size and family composition on poverty in rural India', *Journal of Policy Modelling*, Vol 24, pp 539-559.

NSSO (1997): 50th Round of Household Schedule 1.0 Consumer Expenditure Data, National Sample Survey Organisation, Department of Statistics, Government of India. New Delhi.

Odum H.T., 1996: *Environmental Accounting: Emergy and Environmental Decision Making*, John Wiley & Sons, Inc., New York, USA.

OTA (1991): 'Energy in Developing Countries', a report prepared by the U.S. Congress, Office of Technology Assessment, OTA-E-486, Washington DC.

Pachauri S. and D. Spreng (2002): 'Direct and indirect energy requirements of households in India', *Energy Policy*, Vol 30, No 6, pp 511-523

Pachauri S. (2002): *An Energy Analysis of Household Consumption in India*, Doctoral dissertation No 14796, the Swiss Federal Institute of Technology, Zurich.

Plas R. & A.B. de Graaff (1988): 'A Comparison of Lamps for Domestic Lighting in Developing Countries', Industry and Energy Department Working Paper Energy Series Paper No. 6 World Bank, Washington D.C.

Ravindranath N.H., and D O Hall (1995): *Biomass, energy and environment: A developing country perspective from India*, Oxford University press.

Reddy B. S., (2003): 'Overcoming the energy efficiency gap in India's household sector', *Energy Policy*, Vol 31, N. 11, pp 1117-1127.

Reddy, Amulya Kumar N and B.Sudhakara Reddy, (1994): 'Substitution of energy carriers for cooking in Bangalore', *Energy - The International Journal*, Vol19, No 5, pp 561-572.

Roger, Revelle, (1976): 'Energy Use in Rural India', *Science*, Vol 192, No 4, pp 969.

Sathaye, J. and S Tyler (1991): 'Transitions in Household Energy Use in Urban China, India, the Philippines, Thailand, and Hong Kong', *Annual Review of Energy and the Environment*, Vol 16, pp 295-335.

Sen, A. K. (1993): 'Capability and Well-Being', in M.C. Nussbaum and A. Sen (eds.), *The Quality of Life*, pp. 30-53. Oxford: Clarendon Press and reprinted (1999), New Delhi: Oxford University Press.

Sen, A.K. (1985): *Commodities and Capabilities*, Elsevier, Amsterdam and reprinted (1999), Oxford University Press, New Delhi.

Smith Kirk R., Michael G. Apte, Ma Yuqing, Wathana Wongsekiarttirat and Ashwin Kulkarni (1994): 'Air Pollution and the Energy Ladder in Asian Cities', *Energy*, Vol 19, No 5, pp 587-600.

Sundaram K. and Suresh D. Tendulkar (2003): 'NAS-NSS Estimates of Private Consumption for Poverty Estimation: A Further Comparative Examination', *Economic & Political Weekly*, January 25, 2003.

UNDP, UNDESA, WEC, (2000): *World Energy Assessment: Energy and the Challenge of Sustainability*, United Nations Development Programme, New York.

WB (2000): *Energy & Development Report 2000: Energy Services for the World's Poor*, World Bank Publication.

WEC (1999): *The Challenge of Rural Energy Poverty in Developing Countries*, World Energy Council and Food and Agriculture Organization of the United Nations

CEPE Reports

Aebischer, B., Veränderung der Elektrizitätskennzahlen im Dienstleistungssektor in der Stadt Zürich und im Kanton Genf. CEPE Report Nr. 1, Zürich, November 1999.

Filippini, M., Wild, J., Luchsinger, C., Regulierung der Verteilnetzpreise zu Beginn der Marktöffnung; Erfahrungen in Norwegen und Schweden; Studie im Auftrag des Bundesamtes für Energie. CEPE Report Nr. 2, Zürich, 23. Juli 2001.

Aebischer, B., Huser, A., Energiedeklaration von Elektrogeräten; Studie im Auftrag des Bundesamtes für Energie. CEPE Report Nr. 3, Zürich, Januar 2002.

CEPE Working Papers

Scheller, A., Researchers' Use of Indicators. Interim Report of The Indicator Project. CEPE Working Paper Nr. 1, ETHZ, Zurich, September 1999.

Pachauri, Sh., A First Step to Constructing Energy Consumption Indicators for India. Interim Report of The Indicator Project. CEPE Working Paper Nr. 2, Zurich, September 1999.

Goldblatt, D., Northern Consumption: A Critical Review of Issues, Driving Forces, Disciplinary Approaches and Critiques. CEPE Working Paper Nr. 3, Zurich, September 1999.

Aebischer, B., Huser, A., Monatlicher Verbrauch von Heizöl extra-leicht im Dienstleistungssektor. CEPE Working Paper Nr. 4, Zürich, September 2000.

Filippini, M., Wild, J., Regional differences in electricity distribution costs and their consequences for yardstick regulation of access prices. CEPE Working Paper Nr. 5, Zurich, May 2000.

Christen, K., Jakob, M., Jochem, E., Grenzkosten bei forcierten Energiespar-massnahmen in Bereich Wohngebäude - Konzept vom 7.12.00. CEPE Working Paper Nr. 6, Zürich, Dezember 2000.

Luchsinger, C., Wild, J., Lalive, R., Do Wages Rise with Job Seniority? – The Swiss Case. CEPE Working Paper Nr. 7, Zurich, March 2001.

Filippini, M., Wild, J., Kuenzle, M., Scale and cost efficiency in the Swiss electricity distribution industry: evidence from a frontier cost approach. CEPE Working Paper Nr. 8, Zurich, June 2001.

Jakob, M., Primas A., Jochem E.,Erneuerungsverhalten im Bereich Wohngebäude – Auswertung des Umfrage-Pretest. CEPE Working Paper Nr. 9, Zürich, Oktober 2001.

CEPE Reports und *CEPE Working Papers* sind teilweise auf der CEPE-Homepage (www.cepe.ethz.ch) erhältlich oder können bestellt werden bei: CEPE, Sekretariat, ETH Zentrum, WEC, CH-8092 Zürich.

Kumbaroglu, G., Madlener, R., A Description of the Hybrid Bottom-Up CGE Model SCREEN with an Application to Swiss Climate Policy Analysis. CEPE Working Paper No. 10, Zurich, November 2001.

Spreng, D. und Semadeni, M., Energie, Umwelt und die 2000 Watt Gesellschaft. Grundlage zu einem Beitrag an den Schlussbericht Schwerpunktsprogramm Umwelt (SPPU) des Schweizerischen National Fonds (SNF). CEPE Working Paper No. 11, Zürich, Dezember 2001.

Filippini M., Banfi, S., Impact of the new Swiss electricity law on the competitiveness of hydropower, CEPE Working Paper No. 12, Zurich, January 2002

Filippini M., Banfi, S., Luchsinger, C., Deregulation of the Swiss Electricity Industry: Implication for the Hydropower Sector, CEPE Working Paper No. 13, Zurich, April 2002

Filippini, M., Hrovatin, N., Zoric, J., Efficiency and Regulation of the Slovenian Electricity Distribution Companies, CEPE Working Paper No. 14, Zürich, April 2002

Spreng D., Scheller A., Schmieder B., Taormina N., Das Energiefenster, das kein Fenster ist, CEPE Working Paper No. 15, Zürich, Juni 2002

Fillippini M., Pachauri Sh., Elasticities of Electricity Demand in Urban Indian Households, CEPE Working Paper No. 16, Zurich, March 2002

Semadeni, M., Long-Term Energy Scenarios: Information on Aspects of Sustainable Energy Supply as a Prelude to Participatory Sessions, CEPE Working Paper No. 17, Zurich, July 2002

Müller, A., Finding Groups in Large Data Sets, CEPE Working Paper No. 18, Zurich, October 2002

Farsi, M. and Filippini, M., Regulation and Measuring Cost Efficiency with Panel Data Models: Application to Electricity Distribution Utilities, CEPE Working Paper No. 19, Zurich, January 2003.

Banfi,S., Filippini, M. and Müller, A., Rent of Hydropower Generation in Switzerland in a Liberalized Market, CEPE Working Paper No. 20, Zurich, January 2003

Müller, A. and Luchsinger, C., Incentive Compatible Extraction of Natural Resource Rent, CEPE Working Paper No. 21, Zurich, January 2003.

Jakob, M. and Madlener, R., Exploring Experience Curves for the Building Envelope: An Investigation for Switzerland for 1970-2020, CEPE Working Paper No. 22, Zurich, March 2003.

Banfi,S., Filippini, M. and Hunt, L. C., Fuel tourism in border regions, CEPE Working Paper No. 23, Zurich, March 2003

Semadeni M., Energy storage as an essential part of sustainable energy systems: A review on applied energy storage technologies, CEPE Working Paper No. 24, Zurich, May 2003

Pachauri, S. and Spreng, D., Energy use and energy access in relation to poverty. CEPE Working Paper No. 25, Zurich, June 2003