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Industrial energy efficiency, economic development and poverty reduction

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Industrial energy efficiency, economic development and poverty reduction

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Abbreviations

GHG	Greenhouse gases
GDP	Gross domestic product
IDR	Industrial Development Report
IEA	International Energy Agency
MDG	Millennium Development Goals
SMME	Small Medium and Micro Enterprises

1. Introduction

1.1 Background

This report has been prepared and organized based on the terms of reference provided by UNIDO (see Annex 1), building on discussions with UNIDO staff during the assignment and, in particular, in-depth discussions at the meeting in Delhi in June 2010. All background reports provided by UNIDO and prepared for the UNIDO Industrial Development Report (IDR) 2010/11 with the working title “Industrial Energy Efficiency for Sustainable Wealth Creation” were reviewed first (listed in Annex 3). The relevance and value of the reports were discussed with UNIDO.

The primary gap in the reports prepared for and provided by UNIDO for review was that the linkages between industrial energy efficiency, economic development and poverty reduction had not been adequately addressed in the earlier reports.

Another issue that remains for UNIDO was discussed in Delhi, namely the possible organization of the IDR. Here my proposal for consideration by UNIDO is that section one as currently planned could be moved. Second, there needs to be short summary of the narrative that UNIDO wishes to present in the IDR 2011. At this time it also appears that UNIDO has too large a boundary and extensive range of topics to be covered and this list has been growing over time. It would be particularly useful to draw a clearer narrative outline is to use the contributions and fill the narrative outline. A possible narrative could be to first make the case for energy efficiency in a carbon constrained world, then move to the importance of energy efficiency for industry – with all the added co-benefits. This can be illustrated with the implications, the many opportunities, the barriers and the required policy response. These would include the many cases and examples from UNIDO’s and its partners’ work that was discussed at the Delhi seminar.

The above could be expanded as follows:

1.2 Suggested IDR narrative

Cheap and abundant fossil fuel-based energy resources and their utilization has driven 200 years of industrialization and accompanying economic growth. The abundance and the relatively low price of energy has allowed the increased leverage of energy to the standard factors of production – labour and capital – to generate higher economic growth than would be possible without the benefits provided by the use of additional energy accompanied by continued increase in energy efficiency in production. This growth, at rates much higher than capital inputs and higher than the population growth rates, has in turn enabled increased per capita incomes, hence, increase benefits of wealth and reductions in poverty. Unfortunately, the role of energy in the economy has been largely ignored by mainstream economists and in the foundations of macro economics. This is about to undergo paradigmatic change.

It is anticipated that both the price and availability of energy will be adversely affected going forward in the coming decades. One likely scenario is simply due to increasing demand pressures combined with the need to search for and recover oil and gas resources from ever more difficult reservoirs, accompanied by increased monetary and non-monetary costs as in the case of the major blow out in the Gulf of Mexico. (See also discussions of "peak oil", but agreement or disagreement with the details of the peak oil theory does not invalidate the above point.)

Even more fundamentally, continued reliance on fossil fuels is under threat by the scientific evidence that increased carbon emissions from fossil fuel use is the main contributor to climate instability, which can lead to catastrophic consequences. All solutions to reduce carbon emissions require declining use of fossil fuels accompanied by the rise in their prices through different mechanisms. Thus, the most likely scenario going forward is a world in which the costs of using fossil fuels will increase sharply and all alternatives remain more expensive.

The above leads to the concern that poor countries and poor people, who have only now begun to benefit from the fruits of industrialization and growth, would fall further behind in a "carbon constrained" (or higher energy costs) world.

In our view, the carbon constraint is a critical turning point in the economic development paradigm to which we have been accustomed to over 200 years and raises new challenges for growth and poverty. BUT the challenges raised can be overcome. Energy efficiency has often gained attention only when the price of energy rose and shortages loomed, but the interest in efficiency always subsided again when the crisis was over. Efficiency has always been underprovided for in public policy because of many barriers, as already widely discussed. But increased attention to energy efficiency provides a fundamental key to unlocking new directions and opportunities for growth, as efficiency is a fundamental component of growth. New growth theory has highlighted the nature and fundamental role of technological change in driving growth, and, economic growth is seen to be the main driver to achieving reduced poverty. Energy efficiency improvements are part of productivity enhancing technological change and as such provide the basis in both theory and from the very detailed micro evidence, a key tool for addressing environmental constraint simultaneously with increased growth and reduced poverty.

This paper deals with only some of the co-benefits of energy efficiency and also makes the case for efficiency as a positive factor for growth and poverty reduction.

1.3 Issues of definitions

It is important to note at the outset that most of the terms used for the topic to be covered in this paper are complex constructs and in many cases, their meaning and usage varies. This is true of the terms industry, energy, efficiency, economic development as well as poverty and methods for its reduction. Hence, before we can engage in this discussion of the linkages between these terms, which are the terms of reference for this synopsis, we need to be clear on what we mean by them – industry, energy and efficiency, poverty, economic growth, and sustainability, together with some implications for the IDR of the meanings used or not used. There is also a brief synopsis of key strands of thought on economic development and poverty reduction – both seemingly straightforward concepts, but they contain within them considerable intellectual content, as well as significant issues that remain contested. It is also important to point out that these concepts are defined and used in different ways by important disciplinary subsets of knowledge and for the topics covered, their meaning and construction often varies between different domains of science and engineering, economics, environment and biology and ethics and philosophy. The definitions and usage of the words – industry, energy, efficiency, growth and poverty – all affect the boundaries of the systemic issues and their linkages that need to be considered.

1.4 Industry

Industry, most generally, refers to the organization of production of an economic good. Traditionally, industrial activities have been grouped under categories such as the primary sector, which largely comprises raw material extraction activities such as mining, food production activities of farming, grazing, hunting and gathering, and fishing; the secondary sector, involving refining, construction, and manufacturing; and, the tertiary sector, which deals with services – education, medicine and the distribution of manufactured goods[1]. It is useful to note here that the primary sector starts with raw materials and natural resources and includes the mining of fossil fuel resources. Each subsequent sector moves further away from raw materials and natural resources. The United Nations International Standard Industrial Classification of All Economic Activities[2], (Rev.4) defines 21 top-level activities (A-U) with group A comprising agriculture, forestry and fishing; group B -mining and quarrying including of coal, petroleum and natural gas.

Based on the ISIC classification of industry, the meaning of "industry" suggested here and which can be used is that that the "industrial sector" is only distinguished from the domestic sector. The industrial sector is composed of all economic and productive activities that produce the goods and services used by people (largely or mostly exchanged through market mechanisms) and excludes those activities within the unit of the household which are mostly for self consumption by the members of that household and do not usually enter into market transactions.

At the same time, we see another use of industry in the energy data and analysis of use. Often, energy use is classified by the household or residential, commercial and industrial or manufacturing sector. The transport sector is often treated as a category on its own given the high percentage of energy use for transport. Except for the residential or household sector[3] and its energy use, all other sectors can be defined by the standard industrial classification of

1 Some have proposed a quaternary sector composed of knowledge industry focusing on technological research, design and development.

2 For more details, see http://unstats.un.org/unsd/cr/registry/isic-4.asp

3 Activities within the household do not consist of market transactions and are not included in the outputs valued for GDP.

economic activities (above) to be industrial. Using the above definition, all production that is included in the GDP comes from the industrial sector and:

Industrial production = GDP = all goods and services exchanged in the market (including those such as public services which are not exchanged in the "market" but are included in GDP based on input costs).

Hence, growth in GDP = Growth in Industrial Production = Proportionate Growth in Energy use except as reduced by 3 methods - (energy conversion efficiency + changes in the production process + shift in demand and production between goods requiring greater energy to those that require less energy input per unit output) = technological change + other such as shift in preference, location of production.

It appears that at UNIDO, and also sometimes in common usage, industry is used to refer only to the manufacturing sector. In this usage, manufacturing (industry) excludes all primary sector activities of agriculture and mining and also all tertiary sector activities of services. Within the manufacturing sector, the useful distinctions are between the different sectors and types of manufactured products and processes – steel smelting, paper, cement, and so on; and the scale of their operations between micro, small, medium and large firms[4]. In the manufacturing sector, the basic materials sector dominates industrial energy demand and a small number of key materials - cement, iron & steel, chemicals (plastics, fertilizer), pulp & paper, and aluminium account for half of global manufacturing industrial energy use.

1.5 Energy

Energy is an amorphous concept that we commonly perceive in many forms – gravitational energy possessed by a body at a height above a reference point; heat energy at temperatures

[4] The definitions of micro, small, medium and large enterprises vary considerably between countries and so while useful for many purposes cannot be easily generalized across countries.

above the ambient; radiant (solar), kinetic, electrical and nuclear are other forms in which we perceive of different forms of energy. The most basic forms are human and animal energy (animate) and these require food as the input that is converted to energy by the body. The most traditional and important non-animate energy for most poor people is bio-mass based energy. This is traditionally from trees, branches and crop residues. Other primary energy sources are fossil fuels such as coal, oil, natural gas and renewable sources such as the sun, wind and hydro. Sometimes the primary sources are used directly as in thermal processes of cooking or heating; transportation or in wind pumps; most of the time these sources are used to generate electricity. Electricity is a secondary form of energy, it is the most modern and convenient, has zero pollution at the point of use, and is irreplaceable for many applications such as lighting, computers, communications, and so on.

Energy is defined in science and engineering as capacity for movement or "the capacity for doing work". Work is scientifically defined as the physical result from moving a mass a certain distance by a force. Energy also has a potential – high temperature heat and electrical power, and, the higher the potential the greater is the usable power. Thus, in science, energy is one key input required for all physical or mental activity or work, and that includes activities by humans, animals, machines or nature, such as through flowing wind or water. The scientific laws state that all work requires a commensurate input of energy. It also states that energy[5] is conserved overall in the universe. Since any activity requires energy inputs, it follows that all economically useful activities require energy inputs. Thus, with reference to scientific principles, there is a very tight cause and effect relationship between activity[6] and energy inputs, and this relationship has an upper bound provided by the laws of thermodynamics[7]. According to scientific principles

[5] Here, the term energy means the sum of conventional energy and mass to take into account nuclear energy.

[6] Work is defined as a mode of energy transfer that changes the energy of a system, as in the raising or lowering of weight, or turning an electrical generator. Power is the rate of energy exchange in units of energy per time and a rate of flow. Tester J.W. et al., page 11.

[7] The amount or quantity of energy itself does not change but is conserved.

that are not in dispute, all work and activities, biological and industrial, require commensurate inputs of energy that is used and transformed into work and waste.

Historically, human beings first relied on their own muscle power fuelled by food energy to carry out all useful activities. This was supplemented and leveraged by tools allowing for greater efficiency and then by the use of animals for additional energy inputs to undertake additional work in farming and for transport. The energy released by biomass combustion provided for additional energy for cooking and heating. Even today, small numbers of native communities, which remain largely outside market transactions, rely primarily on these traditional forms of energy. Worldwide, until the mid to late 1700s, human and animal energy (fuelled by food from plants and animals) was assisted by burning wood and harnessing rivers and wind (for water pumping and sailing) to comprise the total amount of energy available for all productive activities. Other renewable energy sources, such as water wheels and wind mills, were slowly added to augment the available human and animal energy for production, and fossil fuels began to find uses with the invention of the steam engine in the early decades of the eighteenth century (Smil, p.4). Starting around the end of 1700, new forms of fossil fuel energy – first coal, which supported the industrial revolution, originating in England, then spreading to Europe and North America. All “fossil fuels” - coal, coke oil, and natural gas derive from underground deposits formed over millions of years of natural processes. By 1900, fossil fuels provided more than half of the primary energy used by society.

It may be useful here to note one small example of activities which would be impossible without the leverage provided by external energy sources. The average human output rate is estimated at 100 watts, for a draft horse it is 1,000 watts and for a compact car 100 Kw (or 100,000 watts). Clearly, it would be economically and mechanically impossible to achieve the transport speed, service and convenience provided by a car if the energy from fossil fuel was replaced by human or animal power[8]. Lighting provides another example, where a single 100 watt incandescent bulb used for three hours provides 1.5 million lumen hours of light per year. This would have required burning almost 15 candles per hour in the same time period, or 17,000 candles in a year[9].

In 1990, the world industrial manufacturing sector (not including electricity) consumed an estimated 98 EJ of end-use energy (including biomass) and 19 EJ of feed stocks to produce US$ 6.7 x 1012 of value added. That is about 30 percent of global primary energy to produce 32 percent of global economic output, providing an average energy intensity in manufacturing of about 17.5 MJ/US$.

It must be noted here and will be discussed subsequently that large numbers of the world population (around three billion people) continue to rely largely on traditional biomass combustion for cooking and heating and that over one and a half billion people do not have access to electricity[10]. The ability of these people to leverage "energy" to increased production is therefore limited. At the household level, energy services are required for domestic needs, small-scale private productive activities and for community services to productive activities in the large scale, for transport, communication and other needs. Energy needs for poverty removal can be pegged at different levels. At the minimum level, basic human needs amount to around 100 Kw hours of electricity per person for lighting and another 1,200 Kw hours (100 kg oil equivalent) for cooking. Beyond that there are no easily defined limits as energy needs for productive activities such as pumping for irrigation, fertilizer, mechanized tilling, agricultural

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[8] Discussed by Tester et al, p. 17.

[9] Nordhaus, William D. 1998.

[10] See, for instance, WHO and United Nations Development Programme, 2009 for the latest estimates; and Smil, Vaclav, 2003 for more details.

processing, industry – bricks, cement and fuel for transport – depend on the levels of production and consumption per capita[11].

1.5.1 Exergy

Exergy[12] is a concept that has been increasingly developed to take into account the two laws of thermodynamics. The first law essentially states that energy in a closed system is neither created nor destroyed and essentially remains constant over time or is conserved. One consequence of this law is that energy is only transformed from one form to another, often from a more "useful" form for doing work to a less useful form. The second law states that all processes tend to increase the total entropy of the universe and at the maximum entropy of a system it is at equilibrium, and thus by definition, no spontaneous processes can occur.

Gibbs in 1873 first identified that not all energy was available for work and introduced the concept of "free" or "available energy" for work. A definition of "available energy" in a system was called "exergy" and was first proposed by Zoran Rant in 1956. Exergy is defined as the maximum theoretical useful work obtained when a system is brought into thermodynamic equilibrium with the environment by means of processes in which it interacts. This suggests that the focus needs to be on the capacity of the energy source to perform useful work (see energy services later). Exergy is defined as the maximum amount of energy that under given (ambient) thermodynamic conditions can be converted into any other form of energy; it is also known as availability or work potential (WEC, 1992b). Therefore, exergy defines the minimum theoretical amount of energy required to perform a given task. The determination of exergy depends on the surrounding environment or reference state. In the case of gravitational, electric and kinetic

[11] Goldemberg in Cleveland et al. 2004 provides some magnitudes of energy inputs required for different kinds of social and production organization.

[12] The thermodynamic roots of the concept go back to 1824, when Carnot determined the principle that applies to the work that can be extracted from a heat engine. See Sciubba, Enrico and Göran Wall, 2007, for a complete historical development and review of the applications of exergy and page 4 for the definition.

energy, the entire energy can be completely recovered as mechanical work and so the exergy and energy are equal for these types of energy while as for heat, the exergy is much lower and is defined by the work output possible by an ideal Carnot engine[13].

1.6 Energy efficiency

Energy efficiency is commonly understood as the ability to produce the same, or greater (more), output (work, services) using smaller inputs of energy.

Given that the energy entering a process equals the energy exiting, energy efficiency is most often defined as the ratio of the "useful output" for the given energy input. In an electric motor, efficiency is the ratio of the shaft power produced to the electrical energy input, and for heating, energy efficiency is the ratio of the heat energy supplied to the home to the energy of the natural gas entering the furnace in the home. This definition of energy efficiency is sometimes called first law efficiency. In 1990, 385 EJ of primary energy produced 279 EJ of final energy delivered to consumers, resulting in an estimated 112 EJ of useful energy after conversion in end-use devices. The delivery of 112 EJ of useful energy left 273 EJ of rejected energy[14]. This would provide a global energy efficiency according to the first law as a total useful energy/total primary energy to be around 29 percent.

Efficiency as defined by the second law (which relies on the exergy concept) uses not only energy quantity but also energy quality as the input. The method here is to compare the amount of work done with the minimum amount of energy that could have been used. The first law efficiency, on the other hand, is simply the ratio of useful energy output to the total energy input. Electric baseboard heaters provide a good example to illustrate the difference between

[13] The exergy calculations for many processes can be complicated. Wall (1986) provides a detailed description of the exergy flows in pulp and paper manufacturing, in a steel plant and in agriculture in Sweden. Hermann (2006) provides some estimates of global primary exergy reservoirs and a research group at Stanford provides a chart of global exergy resources.

[14] Nakicenovic, Nebojsa, et al., 1995, page 78.

two efficiency measures. The first law efficiency of electric baseboard heaters can be considered as being 100 percent because all purchased energy is converted into heat. However, if the system is expanded to include a power plant, overall efficiency drops. Ross and Williams[15] have calculated the second law efficiency of electric baseboard heaters to be 2.5 percent, considerably less than the value of first law efficiency.

Other factors remaining equal, higher energy efficiency means that less primary energy is needed to achieve a given level of output (GWP). More efficiency means less need for the combustion of fossil fuels and less GHG waste emissions to the atmosphere. To move from the physical definition of energy efficiency to economically useful measures, the most common is the energy intensity measure. Energy intensity is simply a ratio of energy input to economic output; an economic-thermodynamic type of efficiency measure[16]. In comparison to the application of thermal efficiency measurement, indices of energy consumption per output defined in monetary units (or physical units for similar economic sectors) can be used to assess and compare energy performance for a broader set of objects: processes, factories, companies, and even countries[17]. Unfortunately, intensity measures are a rough surrogate for energy efficiency. They mask the difference between first and second law efficiency, and mask structural changes that do not represent efficiency improvements.

Output and efficiency measured in common physical units are only possible at lower levels of aggregation, but even at the two or three digit level of industrial classification, common physical output measures are often not possible. Differences between intensity measures using physical output and others using economic output vary due to errors in price indices[18], the nature of

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[15] Ross, Marc H. and Robert H. Williams. "The Potential for Fuel Conservation" in Technology Review, February 1977, pp. 49-57.

[16] Compton, Mallory 2009.

[17] Sometimes, the inverse measure or energy productivity is used.

[18] Nordhaus, William D. (1998) provides a thorough discussion and calculation of this fact using a simple energy service, namely lighting. He estimates that the change in efficiency in energy required for lighting

specialization and products and others. Most importantly for this paper is the point made by Nordhaus[19] that price indices do not capture well the sectors with rapid technological change, almost two thirds of the modern economy. For a more detailed review, see Compton (2009).

1.7 Economic growth

There is a fundamental issue concerning the relationship between energy and economics - the extent to which energy availability and prices affect economic growth and whether economic growth can be decoupled from rising energy inputs[20]. Economists normally use "economic growth" as a measure of the increase in the quantity of goods and services produced in an economy. In practice, it is most often measured by the increase of gross domestic product (GDP)[21] or a similar measure of aggregate income in an economy, and measures the net total of market transactions as the product of all individual goods and services multiplied by their market price/value.

Economists have considered that outputs in an economy are generated from a set of inputs. The production in an economic process is a function of the inputs, the production factors:

$Y = F(x_1, x_2, \ldots, x_n)$;

Where Y is the total output, x_i are the key inputs[22].

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means that in the hundred years of the twentieth century, the work required by an average worker in the US is roughly 10,000 times less than what was required at the beginning of the century.

[19] Ibid.

[20] This is crucial because the threat of GHG-driven climate change means that measures to reduce fossil fuels for energy production has become increasingly important.

[21] Other measures used can be the Gross National Product (GNP).

[22] This is a very general formulation on which there is little disagreement. As discussed later, the questions that are important are what are the important inputs; their nature; their dependencies or independence; the nature of the function F and their measurements. For simplicity and to use calculus, it is assumed that the function is continuous and that it follows a particular shape called the Cobb Douglas,

1.8 Factors of production

In economics, the "factors of production[23]" or "key inputs" that are utilized to produce goods and services were initially seen to be land (natural resources, 'gifts' from nature), labour (the ability to work), the human effort used in production and capital goods (human-made tools and equipment), which are used in the production of other goods. These include machinery, tools and buildings. Classical economists such as Adam Smith, David Ricardo and their followers focused more on physical resources in defining its factors of production and the distribution of cost and value among these factors. Land or natural resource includes naturally-occurring goods such as water, air, soil, minerals, flora and fauna that are used in the creation of products. Land was considered a key factor of production in the earlier pre-industrial and more agricultural periods by all classical economists. The rise of manufacturing in the nineteenth and twentieth century reduced the share of GDP from agriculture in Western countries to below 10 percent and the importance of land in economic considerations declined. Over time as manufacturing industry became more important to the economy, economists tended to drop land as an important input and economists began to focus on special features of manufacturing such as increasing specialization and increasing returns to scale[24].

Robert Solow is considered the exponent of the standard modern growth theory (Solow 1956) where economic output[25] is defined by inputs of labour and capital and growth can take place due to increased capital, labour or to an environmental variable called technology. Theory

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and is differentiable, as closed form solutions are available. Under these assumptions, the price of each factor unit is its contribution to the marginal output.

[23] They facilitate production but do not become part of the final product, as do raw materials, nor do they become significantly transformed by the production process. Here, energy can be seen to occupy a peculiar role. As we claim in the first law of thermodynamics, the total energy in the system remains constant, neither created nor destroyed, and could count as a factor. But according to the second law, the useful component of energy (or exergy) is used up in the production process as is the case with fuel used to power machinery or vehicles.

[24] The famous example of the pin factory provided by Adam Smith.

[25] This is on the supply side and the model assumes that there are no demand constraints.

assumes that production of goods and services (in monetary terms) can be expressed as a function of capital and labour (though in reality, the major contribution to growth is attributed to the remainder that is not explained by capital or labour inputs, but is an unexplained driver called technological progress).

Thus, we can write:

$Y = A*F(K, L)$

where K is the capital stock, L is the stock of labour and A is a productivity factor which reflects the existing stock of knowledge and the resulting efficiency of capital and labour in producing final output. Growth in output thus results: (i) from the accumulation of production factors K or L (one could also include human capital H in addition to K and L); (ii) from increases in the productivity factor A, that is, from productivity growth. As mentioned before, land was important in earlier models developed by economists, but was seen to be less important for industrialized countries and was dropped even though its importance in developing countries remained. Notable for this paper is that energy is also a missing input in this model.

This model could only explain about one third of the economic growth and the balance "Solow residual" which is attributed to exogenous technological progress. The main advantages of the Solow model are the relative simplicity of the model, the fact that it is tractable, and that it highlights the role of capital accumulation and, even more important, the role of technological progress.

Ongoing work has since then been undertaken to improve the Solow model and to increase its descriptive powers. Additional variables have been incorporated to make the model more adaptable to the empirically observed growth experiences of countries and to remove the residual of technical progress and make technological change an endogenous variable, which is generated by the economic process[26]. Over time it was agreed by most economists that human capital and technology were certainly linked to economic growth. However, later it was argued that they could well be the proximate causes of economic growth, but might not be the underlying factor. Some consider the more fundamental causes of economic growth to be some luck or random event, geographical factors, institutional or cultural differences[27]. Important additions have included "human capital" (labour's education and skills), with some decomposing it further to education, experience, "social capital[28]" and intellectual capital. Ultimately, the number and definition of factors varies, depending on theoretical purpose, empirical emphasis or school of economics. Marx considered the "productive forces" to be labour; the subject of labour or the objects transformed; and the instruments of labour or means of production. For him the subject of labour referred to the natural resources and raw materials, including land.

Both casual observation and physical intuition have convinced many investigators that production in the real world cannot be understood without taking into account the role of materials and energy. The standard theory of growth assumes that energy (or work) is an intermediate good that is produced by some combination of capital and labour or just capital (or 'human capital'). The implication is that energy is not a factor of production, hence, growth can take place with or without energy, and there is therefore no reason why energy should not decouple from growth in absolute terms.

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[26] For instance, Mankiw, N Gregory & Romer, David & Weil, David N, 1992. "A Contribution to the Empirics of Economic Growth," The Quarterly Journal of Economics, MIT Press, vol. 107(2), pages 407-37, May, found that the Solow growth model's explanatory power is improved when accumulated human capital is added to the factors that promote growth. Robert E. Hall and Charles I. Jones in "Why Do Some Countries Produce So Much More Output Per Worker Than Others? February 1999, Vol. 114, No. 1, Pages 83-116 found that beyond the above productivity, growth and output are driven by differences in institutions and government policies, which they labelled social infrastructure.

[27] Knowledge, ideas and values, and human relationships are transmitted as part of the culture.

[28] The stock of trust, mutual understanding, shared values and socially held knowledge that facilitate the social coordination of economic activity.

According to the mainstream, scarcity and high energy prices should not have any effect on total economic output, but the recessionary effect of the price shock induced by the rise of oil prices in 1973 initiated increased interest by economists and policymakers on the role of energy in the economy (as well as on energy conservation and efficiency)[29]. Several attempts to incorporate energy as an additional factor of production in the late 1970s and early 1980s ran into a problem, namely that economists were convinced that the importance of a factor (as measured by its output elasticity) must be equal to its "cost share" of GDP.[30] There have been many observers who have noted the critical role of energy,[31] but overall, their work did not influence mainstream economics. Several researchers noted[32] independently following the global economic slowdown with the oil shocks of the 1970s and 80s and wondered whether the role of energy in the economy was being under-valued. Their analysis convinced them that the price of oil (which was used by Solow in his analysis) underestimated its productive contribution[33]. They find that the primary energy consumption is highly correlated with growth. Ayres and Warr 2009 argue for an even stronger causal relationship between economic growth and

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[29] Georgescu-Roegen, N. 1971. The Entropy Law and the Economic Process actually predated the rise in interest in energy and the economy caused by the rise in the price of oil.

[30] Robert U. Ayres, If industrial energy efficiency pays – why is it not happening?, version 15 July 2010.

[31] One of the earliest is W.S. Jevons, who in 1865 dealt with questions on the depletion of coal resources in his book "The Coal Question" and first raised Jevon's paradox, which is of great relevance to the question of impacts of energy efficiency and energy use. Frederick Soddy, a chemist who was awarded the Nobel Prize in 1921, undertook a "quixotic campaign for a radical restructuring of global monetary relationships" (see wikipedia) offering a perspective on economics rooted in physics and the laws of thermodynamics, in particular, and was "roundly dismissed as a crank". In 1921, he published "Wealth, Virtual Wealth and Debt," one of the first books to argue that energy is at the heart of economics.

H. Hotelling did early work on the economics of exhaustible resources (incl. fossil fuel), developing the Hotelling rule. Georgescu-Roegen was one of the first to expound on energy in the economy in 1971. Georgescu-Roegen, Nicholas, 1971. The Entropy Law and the Economic Process, Harvard University Press, 1971.

[32] See, for example, Kummel, Reiner, 1982 and Ayres, Robert, 1976.

[33] Hannesson, Rognvaldur, 2002. Energy Use and GDP Growth, 1950-97, OPEC Review, Vol. 26, No. 3, pp. 215-233, September 2002. The models by Kummel and Ayres predicted that for every 1 percent increase in energy inputs there is a 0.7 percent increase in GDP on average and hence a 1 percent reduction in energy could cause a corresponding drop in GDP of 0.7 percent.

primary energy as converted into "useful work". Warr et al. in a study on economic growth in the UK between 1900 and 2000 find it fully explained by a 3-factor production function - capital, labour and exergy - without recourse to any assumptions of technological progress or total factor productivity, suggesting that useful work/ exergy is an important factor of production. Another paper examining US economic growth since 1900 shows that exergy inputs in a production function accounts better for growth.[34]

All of this strongly suggests that less "available energy" (capable of doing useful work) from fossil fuels would mean less economic growth in the future. To make this point clear, should energy prices double, many transport operations would become unviable, reducing agricultural outputs. Similar slowdowns would affect all economic sectors. Should there be an energy/carbon constraint, then GDP will be highly correlated with energy availability.

Ultimately, the nature of the link between energy consumption and GDP remains a subject of considerable debate among economists,[35] but what can be concluded from this review is that some of the efforts to link the scientific facts with economic theory have not worked well enough to convince all sceptics so far. Nor do we believe the approaches of applying econometrics to determine whether energy use causes growth or growth in production drives energy use, are likely to produce confirming evidence for several basic reasons in statistics[36].

[34] Ayres, Robert U. and Benjamin Warr, 2002.

[35] Banerjee, Abhijit V. & Esther Duflo, 2004 show that the evidence does not support the assumptions of the aggregate production function, whose properties are tied to the assumption of optimal resource allocation in the economy. They show that extensive evidence contradicts the assumption of optimal resource allocation and highlights the more fundamental role of credit and capital constraints due to poorly functioning credit markets.

[36] Zaman, Asad, 2008. Causal Relations via Econometrics, 30 August 2008.

2. Poverty

A general and dictionary definition of poverty is "The state of one who lacks a usual or socially acceptable amount of money or material possessions[37]". This definition already begins to suggest that the meaning could be seen in terms of a lack of absolute levels of material possessions or relative levels. It also suggests that there is a dynamic aspect of poverty and that the concept of poverty varies from time to time and from society to society. What is "socially acceptable" in many poor countries is quite different from the acceptable levels in Europe or North America.

The most basic definition of poverty in its classical form is the absence of incomes necessary to acquire the minimum calorific inputs required to sustain life. This was the approach used by Rowntree (1910) in his study of the city of York, England. Poverty can be defined as a lack of a socially acceptable minimum amount of money or material possessions. This can be in terms of an absolute level of material possessions or a relative level. There are further issues of its constituents and components over time (which we touch upon later). The most basic measure of poverty is the absence of income necessary to obtain the minimum calorific inputs required to sustain life[38]. Most poverty lines today use a similar approach of first defining a basket of goods considered to be the minimum necessary to sustain life[39].

This concept is also applied to the widely known measure of poverty introduced by the World Bank in the 1990 World Development Report. The World Bank defined the poor as those whose per capita expenditure was below US$ 1 per day[40]. The concept of a US$1/day poverty line

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[37] Merriam-Webster's Collegiate Dictionary, 1995.

[38] Rowntree (1910)

[39] The MDGs refer to US$1/day per person poverty line, which is characterized by simplicity and convenience. This concept, more specifically of per capita expenditures below US$ 1 per day (expressed in 1985 PPP dollars) was introduced by the World Bank in its 1990 World Development Report.

[40] This is expressed in 1985 PPP dollars, where PPP refers to per capita household expenditure converted by adjusting for the purchasing power parity for different regions.

appears to be a simple and convenient benchmark to define poverty. But such definitional simplicity obscures many contentious issues including the measurement issue. The 1980 World Development Report described poverty as a condition characterized by malnutrition, illiteracy and disease. This is also in keeping with the definition of Sen that poverty is *an absence of certain 'capabilities'* required to function effectively as a human being which includes education, health care, and so on. This increasing composite view of poverty in turn led to the development of the Human Poverty Index by the UNDP[41].

The World Bank and others concerned with the reduction of poverty acknowledge the importance of the other dimensions for defining poverty. They cite access to health services, education and power or decision-making as well as levels of income, consumption and exposure to risk as issues affecting the poor. A reasonable and practical approach to the multiple dimensions of poverty is a hierarchical matrix developed in the Philippines (ADB, 1999). This starts with the premise that the highest need is survival. The survival need requires a basic minimum of food / nutrition, health, water / sanitation and clothing. The second level is security. Here, the needs are defined as shelter, absence of violence, security of income (a dynamic and not static concept) and employment. The third level includes 'enabling' conditions which includes education, skills, participation, family network and psycho-social needs. For these three hierarchical levels, a total of 33 indicators have been developed.

Finally, many argue that poverty cannot be measured simply by the presence or absence of 'adequate' levels of consumption and certain goods and services, however defined, but that it is a relative concept. It should be analysed by the distributional effects within a given society and also between societies. Taking a consensus of the views expressed in the documents and from a number of country dialogues of the ADB, we may conclude that some basic indicators of poverty are inadequate levels of:

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[41] A composite of three values, per capita income and standards of education and health.

Table 1 Some standard components of poverty

1.	Food
2.	Nutrition
3.	Health
4.	Water/sanitation
5.	Clothing
6.	Shelter
7.	Security
8.	Income
9.	Employment
10.	Education
11.	Skills
12.	Participation
13.	Family
14.	Psycho-social needs
15.	Equity and distribution

We will use these 15 indicators later to see where and how energy interventions improve their availability.

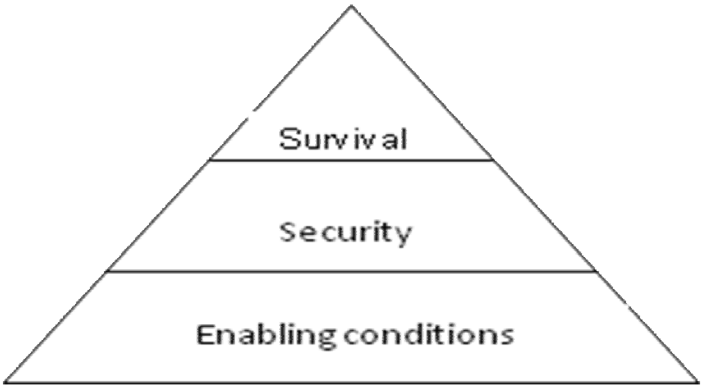
2.1 Poverty beyond income

A way to capture the multiple dimensions of poverty is through a hierarchical matrix which starts with the premise that the most basic need is survival. Survival requires a basic minimum of food/nutrition, health, water/sanitation and clothing. The second level is security. Here, the needs are defined as shelter, absence of violence, security of income and employment. The third level includes 'enabling' conditions and these comprise education, skills, participation, family network and psycho-social needs[42].

Finally, we must also remember that many argue that poverty is not only the presence or absence of some *absolute* minimums, but must also include the distribution within groups and

[42] For these three hierarchical levels, a total of 33 indicators of poverty have been developed by the ADB.

individuals. Poverty is also a dynamic concept in that it can vary over time and between societies. What is "socially acceptable" in Haiti is likely quite different from what is “socially acceptable” in Chile. As economic conditions in a society improve, the perception of "minimum necessities" evolves[43].



We must mention the work of Amartya Sen[44] here, as it is seminal in the field of poverty. Sen states that poverty is an absence of certain ‘capabilities’ required to function effectively as a human being, including better education, health care, and so on. In his formulation, ‘capability’ improvements lead to higher incomes but higher incomes do not necessarily lead to higher capability. Similarly, in accordance with Sen’s thinking, there are a number of poverty dimensions which underpin the MDGs, such as access to health services, to education and decision-making, as well as levels of income, consumption and exposure to risk.[45]. Keeping a multi-dimensional perspective is important for gender work as when poor people, including women, describe their own situation, they often define their well-being as being inadequate because they lack access to sufficient food, water, clothing, shelter, sanitation, health care, and education, as well as income. Women and men place these needs in different order of

[43] Kanbur and Squire, 1999.
[44] Sen 1981.
[45] For example see World Bank.

importance and that is another reason for having gender disaggregated data, and we discuss some of the special concerns of women later.

2.2 Strategies and approaches towards poverty reduction`

If we take the definition of poverty to be the lack of income and capacity to acquire a minimum basket of goods and services (as defined by the MDGs for current practical purposes), then economic growth and the redistribution of income towards increased equality clearly become the two principal mechanisms for poverty reduction. Economic growth has a positive effect on poverty reduction through increased employment and income earning opportunities. They can be followed independently (provided the chosen economic growth strategies do not worsen income distribution) or simultaneously. Economic growth has a positive effect on employment and poverty reduction. Overall, the poor gain from broad-based economic growth (Kanbur and Squire, 1999), and on average, absolute poverty falls with economic growth.

There has been considerable debate on the value of each of the above strategies and the extent to which there are tradeoffs – that is, whether growth-promoting strategies worsen distribution and whether distributive strategies reduce growth rates. At this time the consensus of economists, policymakers and the international development community is that *"economic growth is necessary for poverty reduction, but most likely is not a sufficient condition to reduce poverty"*.

But what causes economic growth? Hogendorn (1992) summarizes the five different factors which influence economic development in very general terms: (1) increasing savings, investment and technology adoption, (2) agricultural improvement, (3) increasing international trade with a focus on comparative advantage, (4) improving economic efficiency (of the system and its agents), (5) human capital formation[46]. Economic growth is not the result of any single

[46] Note here that in this review of the literature on growth, there is little or no acknowledgement of any role for energy. The same lack of discussion continues in most standard discussions and organizational

one of the above factors, but rather a complex amalgam of economic and social determinants. These include, among others, initial endowment, availability of capital (physical, natural and human), technical improvements, cultural and institutional differences, etc.

The most dramatic evidence of the largest poverty removal effects has been observed in the East Asian countries. In 1975, approximately 60 percent of the population lived below the poverty line and after twenty years of high rates of growth, ranging from 6 – 12 percent annually, reduced the numbers of absolute poor to 20 percent. Similarly, poverty in India has declined from a range of between 50 and 65 percent in the mid-1960s to less than one quarter today. This steady decline in poverty was strongly associated with agricultural growth. Public investment in rural areas benefited the poor through its impact on the growth of the rural non-farm economy. And government expenditure on rural poverty and employment programmes, which has grown rapidly, has directly benefited the rural poor (Fan et.al. 1998). As the noted Indian economist Pranab Bardhan states "In the areas where growth has been the strongest poverty has fallen the most. The problem is that by itself (growth) is not enough" (IFPRI, 200 In Brief, September 1999).

Considerable debate remains on the value of various growth strategies and redistributive measures. At this time, the consensus of economists, policymakers and the international development community is that economic growth is necessary and the most important requirement for poverty reduction. Yet, other simultaneous mechanisms focused more directly on the poor are also required. A significant share of economists would also suggest that not all growth is equally desirable. The new paradigm of “sustainable development” is encapsulated in Agenda 21[47]. Here, while growth is given the highest priority for poor countries, a distinction is made that growth strategies must be sustainable over the long term. This requires simultaneous

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responsibilities on macroeconomic issues where growth is located versus the micro-economic issues where energy is one of many sectors reducing the influence of one or the other.

[47] See http://www.un.org/esa/sustdev/documents/agenda21/index.htm for details.

consideration of environmental and equity dimensions. The earlier concern of tradeoffs between growth and equity has given way to a general agreement that "paths that promote growth together with equity and a concern for environmental assets and constraints are available and provide the best course for long-term development" (Munnasinghe, 1999). Thus, investments and policies that complement each other and promote all dimensions simultaneously or at least do not worsen one dimension while promoting another are to be favoured. Many of these recommended policies, however, are broad in their application and do not specifically target the poor. For example, such policies may promote macro-economic stability, increases in overall productivity, infrastructure such as energy services, roads and communications, good governance and expansion of education. Nonetheless, all of the policy-related issues have considerable impacts on all dimensions of poverty. It is, therefore, very difficult, often impossible, to isolate the cause and effect relationship between these broader actions or a single intervention and their direct impact on poverty. These broader policies and actions must ultimately rest on a theoretical understanding of development processes and desired social goals.

Most policies today attempt to support broader actions while at the same time directing some of their efforts at targeted programmes of poverty reduction. Such pro-poor[48] programmes aim to provide income generating opportunities for the poor through public works and rural enterprises; furnish assets such as finance and livestock; promote micro and small enterprises; strengthen organizations of the poor; protect against risks, increase access to education and health care, and so on. In the next section, we will see how increased energy access and use are important in both promoting growth and poverty reduction, and how shortages have significantly constrained both growth and poverty reduction.

[48] The term "pro-poor" does not mean encouragement of poverty, but policies, programmes, and actions that focus on ultimately improving the welfare of poor people in a sustainable manner.

Almost all poor people, particularly poor women, suffer from an interlocking set of disadvantages including inadequate incomes, assets, education and health, lack of security, violence and lack of voice. The rural poor often suffer even more from these disadvantages than others. For instance, the rural poor often live in more remote areas for which it is more difficult to provide infrastructure and services, and access to market opportunities is severely limited. Additionally, they are often less involved with the more productive formal sectors of the economy. What this means is that income and employment, two intertwined aspects, are both highly precarious, unstable, provide few non-monetary benefits (i.e., minimal health packages that might be offered through formal sector employment), is primarily survival oriented and may often have the whole family, including children, involved. Therefore, just as poverty has many dimensions, efforts to reduce it must be equally multi-faceted and synergistic.

In general, food production, income from livestock, cash crops, non-farm activity and other informal economic activities, which provide most of the income for the rural poor, must be taken into account. The rural poor have special needs to improve access and to make better productive use of local resources such as land and water and their local knowledge assets. Often, higher shares of these resources, improved access and control of the assets, institutions, improved technologies and markets, and public infrastructure investments are needed in order to increase their shares of economic growth.

2.3 Energy as a part of the solution to poverty

The removal or significant reduction of poverty with improved equity is the overriding objective of the MDGs. The MDG declaration often refers to the 1.2 billion people[49] who are mired in "extreme poverty", living on less than one dollar a day[50] as being totally unacceptable. Most of the Millennium Development Goals and poverty targets could potentially be achieved if the

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[49] People is used in this document throughout to refer to groups of men, women and children where common group characteristics are being discussed or there is no gender disaggregated data available.

[50] IFAD- Rural Poverty Report 2001 – The Challenge of Ending Rural Poverty.

poorest and most disadvantaged people achieved both increased incomes and increased access to a number of enabling services. Increased incomes allow people to acquire most of their needs from the market, including many energy services. It is important to note here an additional difficulty with accessing many network needs provided by infrastructure, such as transport, energy, health and similar services that often have scale requirements (for instance, a road cannot be acquired individually) and frequently need community or public investments and management above the requirements of income. This is especially relevant for poor women in rural areas[51].

The (MDG) goals are designed towards providing direct improvements in poor people's lives and are ends in themselves. They are arguably also "human capital inputs" for further human development and remain the best examples of "pro-poor" policies that we have today. But energy services, which can make a significant contribution both to growth and to the extent to which growth impacts on poverty levels have been under-emphasized in the early formulations. This has been highlighted in the report by the UN Millennium Project and several other reviews of MDGs. To date, the role of infrastructure and investment in energy services have remained limited, either by a lack of clarity on the more indirect mechanisms through these investments to reduce poverty and by a lack of methods to assess poverty impacts.[52]

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[51] It is useful to note that many deprivations, including of energy in urban areas, are simply due to a lack of income, which prevents the poor from purchasing the bundle of goods and services available in the market. In rural areas, on the other hand, individual income alone does not necessarily resolve the lack of access as the generation, distribution and service infrastructure is also required and absent.

[52] Millennium Project Report to the Secretary General (2005) Investing in Development: A Practical Plan to Achieve the Millennium Development Goals, page 43. The report is especially noteworthy in its consistent focus through the entire document on the energy needs of the poor. It is likely that the lack of attention on energy services in the MDGs stems from the absence of energy in the economics of growth, discussed in the earlier section.

Box 1 Energy services and MDGs

Improved energy services - including modern cooking fuels, access to electricity, and motor power - are necessary for meeting almost all MDGs. They can reduce child mortality rates and improve maternal health by lowering indoor air pollution. They can reduce the time and transport burden of women and young girls by reducing the need to collect biomass. And they can lessen the pressure on fragile ecosystems. Electricity is critical for providing basic social services, including health and education, and for powering machines that support income-generating opportunities, such as food processing, apparel production and light manufacturing.

Source: Millennium Project Report to the Secretary General (2005), page 30, Box 3.1

Given the importance of the MDGs, it is noteworthy and highly positive that the new report[53] goes a long way to reintegrate energy services more centrally into the plan of action to achieve the MDGs and reintroduces energy as a key input. It highlights that a key infrastructure for achieving the means to a more productive life includes essential "energy, including electricity and safe cooking fuels"[54] and it acknowledges that "energy services are vital" to the goals.

We conclude here that appropriate energy services for the rural poor and women can increase their assets, productivity and health can be designed in small packages, run by decentralized local institutions, increase participation, voice and security. When the actual energy needs and the local energy resources form the foundation for designing solutions for energy poverty, keeping the above characteristics in mind, they can and have been shown to act synergistically to improve multiple dimensions of poverty as well as meeting immediate needs. The synergy unfolds with access to assets and technology reducing asset inequities, empowering the poor as well and increasing their incomes. Decentralized solutions contribute by being divisible into small low-cost units and by increasing local control over local natural resources which generates access to financial services, and acquisition and contributions to locally relevant knowledge and increased participation in local markets.

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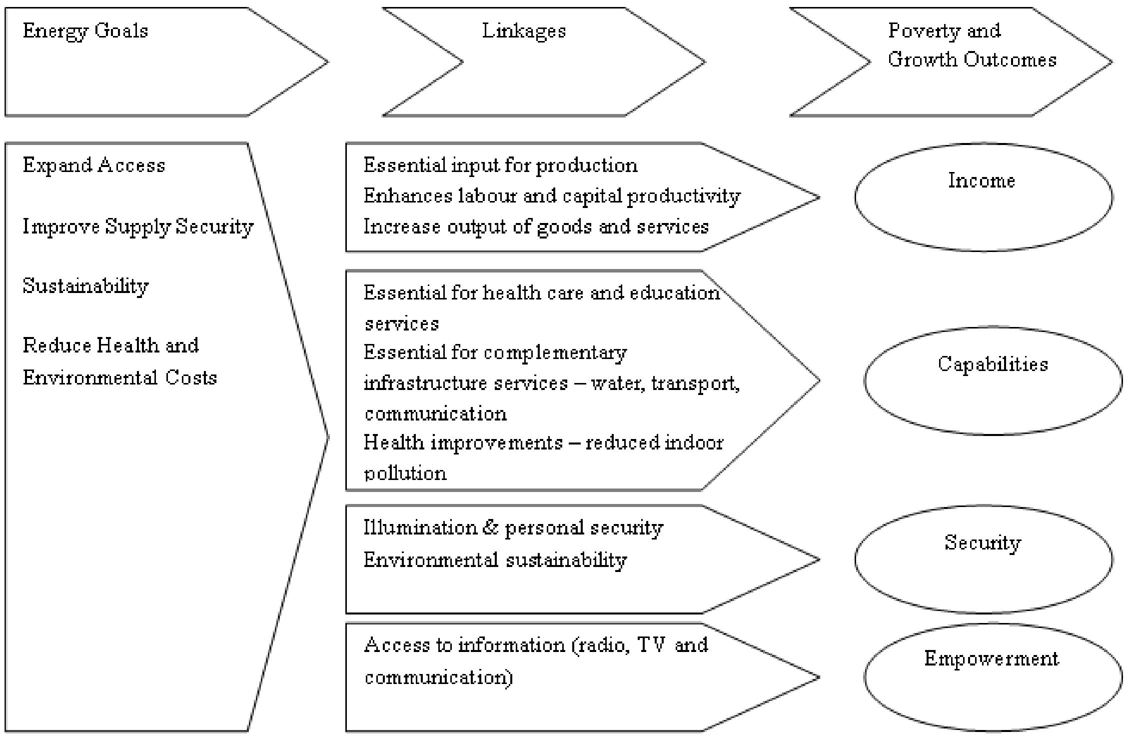
[53] Ibid., page 8. This report also integrates direct and indirect mechanisms in Figure 3.1.

[54] Ibid., page 8, Box 1.3. It also lists other core infrastructural services required for the MDGs and recommends that infrastructure investments must be introduced early in the cycle.

Participation gives poor women a voice. Voice adds to their power to discover and adopt means to improve their own lives. Policies must integrate rural women and girls, in particular, to remove cultural, economic, legal, infrastructural and knowledge-based obstacles to equity. When women are empowered to make decisions concerning household and productive resources, hence resulting in higher incomes, there are many subsequent benefits that materialize for women, for men, and their children in all survival dimensions and with respect to nutrition, health and education. Influence in and over institutions that serve them, often badly, is critical if public infrastructure investments are to be increased and made more effective.

The diagram below illustrates the role of increased energy services and energy efficiency improvements that provide additional energy resources at a lower cost to improve the overall performance of all energy and economic goals, including poverty and growth.



Source: Diagram based on the World Bank Poverty Reduction Strategy Sourcebook and Lamech et al., 2000 p.3.

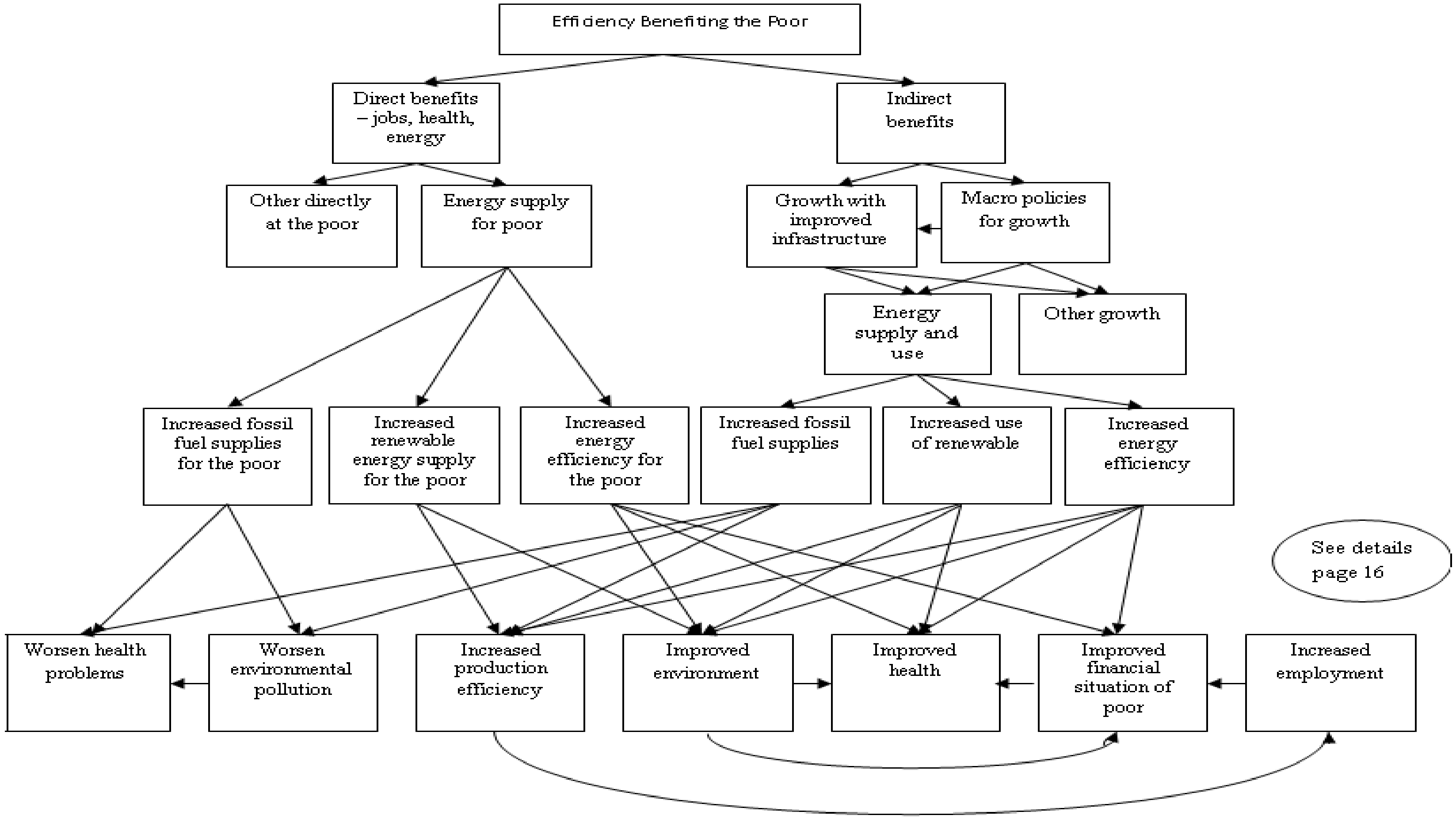
Apart from the energy sector's link to poverty, similar links also operate through energy inputs for other basic infrastructural inputs such as transport, communications and others. Each one of them can have a targeted and direct impact on the poor to the extent that they utilize these services. In all of these cases, the indirect effect is much larger and yet more difficult to establish. Adequate energy services in all countries are growth promoting and their shortage is a critical barrier to poverty removal.

It does not immediately follow that all actions to promote energy supply will lead to positive developmental outcomes. This is because it is not the energy itself which we value but the uses that stem from the availability of energy services. Given that energy supplies carry with them additional capital, resource and environmental costs, alternatives which enhance the efficiency of energy use are to be preferred over an increase in energy supply, if both options provide similar economic rates of return. Hence, economically attractive energy efficiency opportunities provide larger contributions to economic growth and thus to poverty removal than similar increases in energy supply.

The table below combines the various points of the above discussions. It presents the impact of increasing energy inputs for the poor and in the economy at large, as well as of improving energy efficiency for the poor and in the productive sector for the fifteen indicators of poverty identified.

	Indicators	**Increasing Energy Inputs**		**Improving Energy Efficiency**	
		For the Poor	**In the Economy**	**In Uses by the Poor**	**In the Productive Sector**
1	Food	Improves	Improves	Improves	Improves
2	Nutrition	Improves	Improves	Improves	Improves
3	Health	Worsens	Worsens	Improves	Improves
4	Water/Sanitation	Improves	Improves	Improves	Improves
5	Clothing	Improves	Improves	-	Improves
6	Shelter	-	Improves	Improves	Improves
7	Security	Environmental security worsens	Environmental security worsens, job security improves	Environmental security improves	Environmental and job security improves
8	Income	Improves	Improves	Improves	Improves
9	Employment	Improves	Improves	Improves	Improves
10	Education	Improves	Improves	Improves	Improves
11	Skills	Improves	Improves	Improves	Improves
12	Participation	-	-	Improves	Improves
13	Family	-	-	-	-
14	Equity and distribution	-	Tends to improve/Associated with improvements	-	Possible

The diagram below details how improvements in industrial energy efficiency can bring benefits to the poor.



Just as there are strong direct and indirect linkages between energy services and poverty, there are equally strong direct and indirect linkages between efficiency and poverty. The direct links come from the fact that everyone needs minimum energy for basic survival - for cooking, lighting, often for drinking water, irrigation, health care, sanitation, education and employment. And, almost always, the poor pay excessively for the energy they use in terms of time or cost or both. In almost all cases, poverty forces the poor to use energy with poor efficiency as in the case of kerosene for light, wood stoves for cooking and in many production activities as well. This often forces the poor to cause and suffer greater environmental harm. Thus, improvements in energy efficiency directed at the poor increase their well-being by reducing costs and increasing opportunities.

Examples of direct impacts for those who live on below US$ 1 per day include lighting where CFL and LED options can increase disposable incomes by 5-20 percent (by reducing costs); in cooking, more efficient stoves can similarly increase incomes; home heating is a major cost in colder regions and the potential for direct benefits to the poor with more efficient systems are significant. The costs can be as high as 30 percent of total income. Finally, in all production activities such as irrigation, thermal applications for post-harvest processes and others can increase production and income with efficient energy inputs.

It must be noted that the indirect impacts can be even larger. In countries like India with electricity shortages of 25-30 percent, a great barrier to increased access is the inefficient supply and use which reduces pressure to increase access. Even if climate change is completely ignored, energy supply and use are the single largest cause of environmental damage in most countries; in some, the environmental penalty on GDP is over 5 percent, penalties often borne more by the poor. An efficient energy system (supply and use) goes hand in hand with an efficient production system, competitiveness, innovation, growth and a host of positives.

2.4 Energy and poverty

"Poverty means, among other things, limited access to energy sources for the required energy services[55]. Poverty influences and determines energy choices of poor households"[56]. The most important point about energy is that no one wants energy for itself, unlike food, shelter or clean air; rather, people want energy for what it allows them to do. People have two basic energy needs for survival in mild climates, energy for cooking food and energy for lighting at night. In colder regions, people also need energy to provide heat. These three together are the most basic survival needs and many poor people do not have access to sufficient energy supply to meet these basic needs.

People need additional energy to increase their production, and mobility. Energy, especially electricity, allows for other benefits including refrigeration and cold storage, motors for pumps and machinery, and communication (telephones) and entertainment (televisions, radios) services and knowledge. Without access to basic energy services for lighting, cooking, heating and for productive purposes such as grinding, husking, pumping, transportation and communication, people, often women, are forced to spend the majority of their time and physical energy on subsistence activities. The poor invariably use traditional energy technologies that are inherently very inefficient in that the final useful energy service derived from them is a small fraction of the energy input. Lack of energy services is directly correlated with the major elements of poverty, including inadequate health care, low education levels and limited employment opportunities. Energy poverty[57] is the lack of adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development.

2.4.1 Energy services for survival

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[55] See earlier section on the many different forms of energy.

[56] Celeski, E. (2003) Enabling Equitable Access to Rural Electrification: Current Thinking on Energy, Poverty and Gender, World Bank.

[57] Reddy 2000.

The linkages between energy and poverty are both direct and indirect. The direct linkages come from the fact that whether poor or non-poor, everyone needs a certain minimum energy for basic survival because of the energy required for the cooking of food, lighting and in colder and higher altitudes for heating of living space. The latter is a need that is relevant for smaller numbers in developing countries and hence is often not given much priority in development efforts. The need for energy for heating, however, is much more significant where the poor live in high altitudes and/or in colder climates. Hence, the need for energy for heating should be factored in in energy-related development plans for the relevant regions[58].

2.4.2 Energy services and other enabling conditions

Energy is often required to provide clean drinking water, health care, sanitation, education and communication. We will not repeat here the many strong arguments made by Barnett (2000) and many others to show the very strong link between energy use and availability in the economy with production, growth rates and a positive Human Development Index[59]. All of these tasks are important to the survival of the household, involving drudgery and time that could be reduced by the availability of modern energy services. Improvements in energy services, both on the supply side and for increased user efficiency, will require higher skills from those involved. This requires training and in turn increases capacity with additional indirect benefits in terms of empowerment and transfers to other activities. Similarly, micro-credit programmes and institutions can help promote the shift to better energy services and also for increased saving, investments in other areas, and thereby promote multiple objectives. These are all too often neglected areas of energy planning.

[58] Many of the poorer regions of Latin America are located in the Central Americas and the Andean countries where the rural poor tend to be in higher elevations and need energy for space heating. Energy required for space heating can be much higher than for cooking, which in turn is much higher than for lighting. In the colder regions without providing solutions for more efficient and cleaner space heating, the benefits from improved cooking stoves are unlikely to be significant.

[59] Barnett, J. (2000).

2.4.3 Energy, production and income

Additional energy inputs remain a key supplement to human energy in order to increase outputs per person. Beyond these effects directly affecting individual welfare, energy is an especially important input for economic growth. A correlation between per capita energy consumption and per capita incomes in different countries and over time shows that low energy consumption is associated with poverty and that the demand for energy rises roughly in step with economic growth. The correlation between energy use and economic growth is further confirmed by the counterfactual in that energy shortage constrains economic growth[60]. Many activities and investments are simply not possible without complementary energy inputs. Historically, in all societies increased agriculture and food production and farm-related services have provided the locus of most employment activities in rural areas and for the poor. Additional production and employment opportunities thus demand complementary energy services.

Micro, small and medium firms (including larger firms) play an increasingly important role in promoting employment, a major element of poverty reduction. The MDG goal of halving the share of people living in extreme poverty cannot be realized without durable, sustainable and broadly-based economic growth, much of it in the smaller scale and in a vibrant private sector. Small scale firms can belong to the energy services sector. Here, they serve to enhance the livelihoods and employment of the poor directly as providers of energy services, as well as the other benefits of employment and income. All manufacturing firms have a special role in energy efficiency as they provide the equipment and services that lead to the efficiency improvement.

Energy resources and their exports are critical for some poor developing countries such as Bangladesh, Bolivia, Ghana and Mozambique. They are blessed (and sometimes cursed) with important oil and gas resources which can prove to be a major source of economic growth, for growth of the private sector development, and for meeting energy services gaps of local people

[60] Ibid. page 6.

and businesses. They face great opportunity to harness the resources for economic growth and increased employment.

Theory and experience suggest that the promotion of an efficient manufacturing sector requires an enabling business climate characterized by well-functioning public institutions and policies that are needed to support a dynamic private sector, and include low transactions costs, efficient credit institutions offering various types of financing, efficient regulations and procedures, increased transparency and reduced corruption, together with access to infrastructure such as the required energy, transport and communication services. Weak public institutions that fail to deliver the required services add to the difficulties of production, growth and profitability.

The enabling environment for growth is not only at the macro level, but needs to be complemented by micro-economic reforms and infrastructure services that help competitive forces. Actions by policymakers in developing countries have focused heavily in recent decades on improving macro-economic policies, undertaking structural reforms including trade policy, privatization and improved financial markets including micro-finance, yet attention to other elements of the microeconomic foundations -- the policies and institutions that support efficient economic activity -- has been uneven. The World Bank claims that more attention is currently required to meet the significant infrastructure deficits, including energy service needs in developing countries, to enhance production and employment opportunities, as well as to help the poor access basic energy services[61].

2.4.4 Energy services on production and growth

In most developing countries, firms suffer from losses in production and productive capacity because of poor infrastructure. Inadequate energy services is often the biggest problem and is cited as an obstacle by up to 30 percent of firms in developing countries as a whole, but by 50

[61] World Bank 2004.

percent in South Asia and 70 percent of businesses in Africa[62]. In Nigeria, poor electricity service was reported by 93 percent of firms as the most significant problem. They reported loss of power more than five times a week meant 88 lost working days per year, and incurred the loss of raw materials and damage to equipment. Smaller firms were more vulnerable and lost 24 percent of their output. In Tanzania power outages affected over 25 percent of the work days and inadequacies in the energy infrastructure was the largest cost element for business. In Bangladesh, conditions are even worse with firms suffering from power loss on over 250 days per year. The World Bank has estimated that Bangladesh loses around US$1 billion per year in economic output due to power outages and unreliable energy supplies. At a macro level, the World Bank estimates that with higher investments in telecom and power generation Africa would have achieved an increase in growth rates in the magnitude of 1.3 percent per year during the 1980-90s.

A USAID evaluation in Bangladesh showed that with rural electrification interventions, the households which had access to electricity had incomes that were 50 percent greater than those who did not; the rate of poverty declined by 20 percent; the income of the poorest (the lowest 10 percent income group) was higher; there was increased agricultural productivity due to irrigation; those with access increased their savings by 30 percent and thus had better access to credit. Commercial activities increased from 9 to 14 hours per day; turnover increased by 34 percent and electrified businesses employed more workers and paid higher wages than non-electrified businesses, with all contributing to a 'virtuous cycle' of increased incomes and production[63]. Another study in Indonesia established the importance of electricity for the development of enterprises and businesses in rural areas. It found that footwear enterprises with

[62] World Bank (2005) World Development Report, page 124 and DfID (2005) P 17.

[63] See USAID in Bangladesh's website, http://www.usaid.gov/bd/Economic Growth.html; Bangladesh – Second Rural Electrification Project, Project Completion Report, World Bank, 1995; Bangladesh - Third Rural Electrification Project, Implementation Completion Report, World Bank, 2000; Bangladesh - Rural Electrification and Renewable Energy Development, Project Information Document, World Bank 2001; and Jocelyn A. Songco (2002) Do Rural Infrastructure Investments Benefit the Poor? World Bank.

electricity had twice the revenue of those without and small enterprises doing embroidery work had eleven times the revenue when they had access to electricity[64].

2.5 Sustainability issues

The growth in energy demand means that many countries are facing financial, operational and environmental constraints independent of any consideration of carbon emissions. For all countries, and especially for developing countries, energy and economic development are closely linked. Economic growth, the primary method for eliminating poverty, requires growth in energy services. But the use of modern energy forms given that global warming, acid deposition, urban smog, and so forth are key environmental concerns, and because of national financial, operational and institutional issues, involves challenges. Specifically, emissions from the burning of fossil fuels for industry, transportation and power generation are the largest sources of urban air pollution[65]. These issues are critically important and need to be dealt with at national and global level, as all current forms of energy are highly polluting[66].

With the acknowledgement at Copenhagen in 2009 of the severity of climate instability and GHG, the issue of reducing CO_2 from fossil fuels has gained prominence in global and national policy discourse and could consequently divert attention from the energy needs of the poor. Here, the issue of focus is on the fact that approximately 2 billion people in the world, predominantly women, depend on traditional fuels (i.e., dung, crop residues, wood, and charcoal) for cooking, and a similar number use candles and kerosene for lighting as they do not have access to electricity. Both cooking and lighting are basic and primary needs and (for those without the need for space heating) account for 90–95 percent of their non-human and animal-

[64] K. V. Ramani and Enno Heijndermans (2003) Energy, Poverty, and Gender: A Synthesis, World Bank, Washington D.C. P. 89.

[65] Industrial production processes add particulates such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and other pollutants to our atmosphere.

[66] Rath (2002).

derived energy. These needs are met by the poor with significant negative effects for themselves and their families. It is important to point out that solutions for the rural poor do NOT put stress on the global commitments.

If we expand the poor who do not have access to energy to the entire group of the world's rural population, it is around 3 billion people. If we then take a rough estimate[67] of the minimum useful energy required by each rural person for cooking and lighting as their basic requirements, and multiply it by the total number of people, the annual energy requirement is around 3000 PJ. The WEC states that "[i]f we were to stretch our imaginations and suppose that these energy needs could all be met by electricity, assuming an 85% conversion efficiency of the electrical appliances used, this would translate into 3472 PJ, or 964 TWh, or only about seven percent of the world's total electricity production in 1996 and less than the residential energy consumed in the USA in 1993!" Given the additional contribution of fossil fuels used for transport, even if we supplied the world's entire rural population's basic energy needs entirely with polluting fossil fuels, this would not add more than 3 or 4 percent to global pollution and carbon emissions.

Global emissions have grown by much larger amounts in almost all countries over the past decade without any benefits to poor people. This should put at rest the almost mindless debates and gross policy distortions whereby the most expensive forms of renewable energy are reserved in donor funding for the poorest! The poor should be provided access to the cheapest energy services that improve their well-being. In some cases, the solutions will lie in improved renewable technologies - biomass, small wind and hydro, but in a large number of cases, it will involve fossil fuels such as LPG for cooking and diesel for transport and electricity. To fully

[67] Developed by the Indian Planning Commission for the cooking and lighting needs of the Indian population as being 1MJ/per capita per year of final useful energy. It must be noted that there is a wide range in per capita rural household energy use, but the data suffers from so many inaccuracies, and of course, there is wide variance in practices that we have not attempted to determine a more accurate global number here. See WEC1995, *Rural Energy in Developing Countries* for more details.

take advantage of growth options, programmes must ensure that the poor have access to investment options for more efficient technologies for energy services.

2.6 Penalties imposed by inadequate energy services

In many cases, the poor pay excessively for the energy they use in either time or cost or both; this cost is typically borne by women and children[68]. For example, traditional biomass stoves have very low energy efficiency and this increases the time burden of those who collect the larger quantities of fuel required than with an efficient stove, a task overwhelmingly allocated to women and children. Beyond the fuel needs, they also increase the time for cooking, again a task typically undertaken by women. In many cases, poverty forces the poor to use energy with less efficiency in production activities as well as in the case of wood stoves for commercial food preparation, in pottery, brick making, drying and processing of agricultural products and in many other traditional activities.

Inefficient production activities often force the poor to both cause and suffer greater environmental harm and damage to their health. Thus, improvements in energy supply directed at the poor increase their well-being both by reducing their costs and increasing opportunities[69]. Fuel wood and crop residues, for example, are inefficient energy sources for cooking in comparison to gas and electricity, which can be five to ten times more efficient. Electricity can be up to 30-100 times more efficient than a kerosene lamp in converting energy to useful light[70]. Thus, where the poor use cash, a greater percentage of these cash resources are used for low quality, less efficient fuels at a greater cost in terms of the health impacts of respiratory diseases and premature death, higher demands on time and the reduced ability to accumulate the necessary financial resources for improving livelihoods. While using fuels more efficiently and in ways less damaging to the environment and to people's health is possible, this is not occurring

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[68] Lamech et al 2000, p. 2.
[69] ESMAP 1999.
[70] Nordhaus, 1998 and similar calculations done by the author.

in large regions of the world; nor is a potential alternative, which involves shifting to modern fuels and[71] which most rural poor in developing countries would consider a blessing, progressing as rapidly as it could.

There was a time when energy was considered a central part of the process of economic and social development. Albeit exaggerated at times, Barnett (2002) laments that energy for the poor often appears to fall off the development agenda as an important factor in the development process, and similarly, the Millennium report comments that over the past 20 years, donors have moved away from the provision of efficient energy services.

2.7 Increased & efficient energy services and poverty

All the evidence available suggests that the reduction in poverty levels will require increased quality and levels of energy services beyond that which is currently available. Clearly, alternatives which use renewable energy and/or increase the efficiency of energy use are always to be preferred when the economic and financial costs are appropriate; too often, efficiency options are completely overlooked.

2.7.1 Manufacturing

Both theory and empirical evidence reviewed here indicate that energy efficiency in the economy and also in the manufacturing industry has a strong link with competitiveness for firms, sectors and the economy through various linkages in all countries. It begins with the fact that firms pay for the energy services used and savings translate to the bottom line. The no regrets potential or the win-win potential for efficiency gains range from 10-50 percent of the energy of most firms and this is significant. Large gains in manufacturing energy efficiency are

[71] The term modern always includes liquid petroleum gas (LPG), kerosene; electricity and coal. It should also include, and increasingly does, modern biomass-based technologies such as improved stoves, gasification and other new energy technologies, as well as renewable sources such as wind, solar and small-scale hydroelectric resources.

associated with newer plants and new technologies, all with higher overall productivity gains. Hence, economy-wide competitiveness would be enhanced with increased energy efficiency. There is plenty of evidence in developing countries that IEE is profitable. The evidence comes from hundreds of individual firm-level case studies. It also comes from econometric evidence from a World Bank study cited by UNIDO for 24 developing countries between 2000–2005 and 10,600 enterprises that Total Factor Productivity (TFP)[72] is negatively related to energy intensity in almost all countries as well as capital to labour.

These productivity results again translate to growth in trade, narrowly first in the energy sector, whether energy is imported or exported, but also through increased trade flows related to investments, technologies and final products. Individual countries that take a lead in the market for energy efficient technologies would gain in higher innovations and productivity growth. Further, all supply of energy efficient technologies, both for use in manufacturing and in other sectors would be provided by the manufacturing sector. Thus, the manufacturing sector is critical to the building up of technological and innovation capacities, together with first mover advantages for trade and growth[73].

Very often measures to increase energy efficiency per unit of output in industrial production activities are highly correlated with an overall increase in production efficiency. Therefore, increases in energy efficiency are likely to be accompanied by lower inputs of other materials, lower wastes and reduced pollution loads. Besides the issues specific to energy production and use, there is concern that unless the impacts of economic and production activities are reduced, they will increasingly generate environmental constraints, which will further limit the scope for economic development besides their negative impacts on the health of human and other living things (World Commission, 1987). More efficient and cleaner technologies are those designed

[72] TFP is related to the Solow residual for technology discussed earlier.

[73] See Eichhammer, Wolfgang & Rainer Walz, 2010 for a longer and more detailed discussion on these points.

to reduce the throughputs and waste streams of energy, water, materials and byproducts and these provide developing countries the choice, often termed “leap-frogging”, to follow less polluting options rather than using outdated technology.

Furthermore, energy efficiency options offer a potential for improving the technology services provided to small and medium industries. SMMEs provide the maximum amount of employment in all countries and are seen as a major element of any employment generating developmental path. At the same time, small and medium-sized businesses tend to be less efficient and more polluting (per unit of production) than many larger units and do not have the in-house capacity to resolve their technical problems. We therefore need to review the special role of SMMEs in growth and employment generation strategies and their special problems and needs.

2.7.2 Small and micro enterprises

If we apply a comparative framework to development and accept that in certain respects the development path followed by developing countries (DCs) will include some of the same elements and follow some of the same trajectories industrialized countries did, then the following historical facts may be considered to be valid. Historically, in all societies the majoriy of people were involved in agriculture and food production, and farm and farm-related services provided the locus of most employment and defined social organization (English, 1993, p. 3). In all countries, additional employment opportunities emerged first with increased farm production and with related off-farm industrial production, both demanding complementary services. It is natural for all such additional production activities to mainly start in small establishments, some in rural and some in urban areas. It is only in the later stages of development that many of these small establishments grew to become large, so that in the industrialized countries a high share of all employed persons worked in large establishments[74].

Over time, with industrialization, there is a movement of labour from the farming sector to manufacturing, with a growth in SMMEs and their employment share. Ultimately, the structure of employment and firms in the industrial sector stabilizes with a certain distribution between larger and smaller firms. This structure and distribution, always a dynamic one, depends on the history, economic policy and industrial environment within which different sizes of firms exhibit optimal economic efficiency. The economic logic for the initial growth of SMMEs is based on the initial scarcity of capital and scale of markets. This is true for all new entrepreneurs in all countries. And, capital scarcity is a more common characteristic for most entrepreneurs in DCs[75]. Over time, some of the SMMEs move toward more capital-intensive technologies as their supply of capital increases. Since capital-intensive technologies tend to be characterized by economies of scale, large firms evolve and become dominant in many sectors over time.

The fact that there is not enough capital to go around in DCs (i.e., not all workers can be allocated similar amounts of capital as in industrialized countries) leaves a country with two alternatives. It can concentrate a high share of its capital on a few workers who will have high labour productivity and high wages and leave the rest of the workers with very little, or it can attempt to distribute the capital more evenly among all workers (English, 1993, p. 6). Normally, one can get more total output by using all of the workers together with intermediate technologies than allowing a few to work with advanced technologies while the rest have so little capital that their productivity is very low (English, 1993). Intermediate and less capital intensive technologies are used in SMMEs to a much greater extent than in larger enterprises.

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[74] The definitions of "large," "medium," "small" and "micro" establishments vary considerably across countries and in many countries there are legal definitions for the different size classes.

[75] Banerjee, Abhijit V. & Esther Duflo, 2004 show that the role of credit and capital constraints is fundamental and pervasive due to poorly functioning credit markets.

Among the most commonly stated rationales for the support of smaller production units is their employment creating capacity. This almost universal phenomenon arises from the fact that generally for the same product, SMMEs use greater labour and less capital and in most countries, most start-ups are in SMMEs. Also, SMMEs usually hire a work force with lower skills and thereby provide a large number of unskilled workers valuable work experience and skills. Evidence also shows that SMMEs often tend to use more appropriate technologies, produce products with more appropriate attributes and at scales more suitable to small DC markets. Finally, it is postulated that, unlike the larger scale manufactures that rely more on imported technologies, SMMEs can provide the main market for DCs' research and technology development capacity. Recognition of the significance of the small-scale sector (SMMES) increased almost two decades ago, together with a better understanding of technology issues and the nature and pervasiveness of employment and poverty problems.

The potential socio-economic contribution of small manufacturing enterprises is considerable and will remain so for some time in most parts of the developing world. The countries that have shown exceptionally high economic growth rates, high employment rates and a more equitable income distribution are Japan, Korea and Taiwan, and all of them have depended on a strong base of small enterprises. In the poor countries around the world, it is clear that this sector must play an important role for the foreseeable future, if they are to increase their economic growth rates while increasing employment opportunities and equity. Another reason for the importance of SMMEs is that in many sectors, production that is closely coordinated between large firms and many small subcontractors has proven to be more economically efficient than that undertaken by vertically integrated large scale firms alone. Other advantages of SMMEs are that their development is important for the promotion of regional economic development. It is also argued that small enterprise development is important for the more efficient functioning of the market by increasing the number of participants and reducing dominant power. Finally, it is argued that small enterprise development promotes democracy and a civil society by increasing the participation of a larger number of stakeholders in the economic, political and social systems. (Additional discussions of the reasons for supporting SMME can be found in the ILO reports and in English, 1993).

All these advantages and benefits of SMMEs do not come without some attendant costs. In many cases, it is understood that the economic penalties of not taking advantage of scale economies when available are simply too high. Even where SMMEs are economically attractive on various grounds they tend to be less energy efficient and contribute higher emissions than larger enterprises per unit of production, and given their geographic dispersion and lower capital and skill base, provide greater challenges for technological upgrading. In general, they are weaker in their capacity to generate savings and to generate technological change. Finally, the reality of health, safety and working conditions and pay, for SMMEs is in general inferior to conditions in large enterprises, although at the macroeconomic level, it may be more “appropriate.” As in the case of small farmers, it is generally accepted that a healthy, efficient and dynamic SMME sector necessarily requires the provision of technological inputs from outside the sector.

For a consideration of energy efficiency, production, growth and poverty, SMME provide special challenges and opportunities for public policy. To take an example from India, the total number of SME units in the country was estimated to be around 0.31 million employing 17.1 million people as of March 1999, thus being the second largest employer of human resources after agriculture. The total production in the sector was US$ 120 billion of which around US$ 11 billion was for exports[76]. The SME sector thus accounted for around 40 percent of total manufacturing production and a third of the country's total exports. It is clear that the sector plays an important role in economic growth, employment opportunities and equity.

The study[77] found that over a period of 50 years, the existing knowledge base of the small firms in the sector remained well behind the knowledge and technology available in the country, but at the same time, knowledge levels were dynamic and continuously improving. Lower levels of skills and formal training and capital barriers are major factors preventing faster learning and higher energy efficiency. The key findings reveal that many examples of energy efficiency options exist that are financially attractive, but a set of existing and complex barriers prevents their implementation. The evidence demonstrates that useful programmes can indeed be

[76] Rath, Amitav, 2001. Mechanisms to Improve Energy Efficiency in Small Industries, Part Five: Conclusions, Policy Research International, DFID Project R7413; page 1.
[77] Ibid.

implemented in all countries and that these programmes can demonstrate immediate and achievable energy efficiency gains which are also economically attractive. Many of the possible interventions were found to be highly cost effective for the user, the economy and the environment. Our findings in Khurja add to the global evidence and confirm the earlier findings that such opportunities are quite extensive and significant in Khurja. But we also found that much of the literature promoting energy efficiency tends to be “noisy” – with degrees of misidentification and misspecification, thus reducing the efficiency of the knowledge transmission process. That adds to the risks for the SMME sector.

2.7.3 Consumption/income

Energy efficiency improvements generate savings and improvements in the production process through lower energy costs, reduction of waste, increased productivity etc. By reducing resource use, energy efficiency improvements will increase the industry's overall efficiency. This increased efficiency will inevitably lead to increased profits. These higher profits can benefit the poor in various ways:

- If the enterprise is a micro size enterprise, the workers and owners of the enterprise are often the same. Thus, reduced costs translate immediately into increased earnings by the poor families working in micro enterprises.
- Where the units use hired labour, the chain of effects becomes more indirect. Profits can be utilized in several ways and normally some or all of the effects below should take place. Some of the increased profits may be redistributed through the industry as increased wages to employees; or, the increased profits can be used for additional investments and production, purchases of inputs and services, creating spin-offs in input-providing and output-using industries and thus promote economic growth. Economic growth has a positive effect on employment and poverty reduction as discussed earlier.

On the other hand, increased savings may be passed on to the user of the output in lower sale prices. If the users are low-income groups, then it improves their incomes. In all cases, the increased competitiveness of the sector should lead to higher production and employment. Or even in the worst case, where the profits are only accrued by the owner who may not be poor, it will lead to higher profitability for the sector, which in turn will lead to expansion of production by others.

2.7.4 Health

As many industrial areas are clustered, the emissions from its factories, stemming from large quantities of fossil fuel burning, tend to have large negative local environmental effects. Small plants, in general, are more pollution-intensive per employee and presumably per unit of output (Dasgupta et al. 1998). By reducing energy requirements through the introduction of energy efficient technology and conservation practices, lower levels of pollutants such as NOx, SO2 and airborne suspended particulates will be present in the area (in addition to the global benefit of reduced CO2 emissions). This benefit will be of greater importance to the poor, as they generally live in the proximity of these polluting factories. Pollution-intensive industries have a tendency to locate in low-wage areas (Dasgupta et al. 1998) for various reasons. Firstly, pollution regulation is often weaker or absent in poorer regions (Pargal and Wheeler, 1996; Wang and Wheeler, 1996; Dasgupta et al. 1996). This may be attributable to the lower relative value assigned to environmental quality by the poor, and/or because low-income communities may be less informed and/or less organized to regulate pollution effectively (Dasgupta et al. 1998).

2.7.5 Education and skills

Any improvement in energy efficiency will require higher skills from workers. It is assumed that important training and education benefits can accrue to workers with reference to energy efficiency and conservation.

2.7.6 Risk and vulnerability

The problem of risk, as Kanbur and Squire (1999) identify, is that it keeps the poor in low-risk, low-return activities and it endangers what they already have. One of the greatest barriers to investment in new (higher-risk, higher-return) technology is access to capital and this problem is even more acute in poorer countries. By providing both information and energy efficient technology, the risk level for pottery entrepreneurs is reduced. This gives them access to a high-return activity with a reduced corresponding risk. It also reduces future risks of owners and workers not meeting higher environmental standards and the risk of not being competitive in domestic and export markets.

Following Bruno et al.'s (1995) conclusions, allowing the poor to make productive investments through either lowered credit constraints or by increasing the available information about new technologies leads to a higher and more equitable growth process.

2.7.7 *Sustainable development*

Overall, energy efficiency promotes sustainable development strategies. According to Repetto (1986, p. 15), "sustainable development [is] a development strategy that manages all assets, natural resources and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being. Sustainable development, as a goal rejects policies and practices that support living standards by depleting the productive base, including natural resources, and that leaves future generations with poorer prospects and greater risks than our own." More simply put, the Brundtland Report asserts "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

As the main energy source for the pottery industry is derived from the burning of non-renewable fossil fuels (as is the case for most other industries and consumers), this practice is both polluting and unsustainable. By finding energy efficient technology for the pottery industry, this will lead to decreased energy consumption and consequently will reduce polluting emissions. The use of energy and its implications are of increasing global and national policy concern. These concerns stem from the perception that a number of human activities and developmental goals and objectives are not sustainable under current and existing "Business as Usual" policies and practices, especially with regard to the uses of energy. Detailed critique of developmental trajectories that are not sustainable are found in the Bruntland Report and in Agenda 21.

Specifically with regard to energy, the current energy use patterns and their anticipated increase and the need to reduce global greenhouse gas (GHG) production and global warming have become important. The majority of GHG, carbon dioxide, is produced by the burning of fossil fuels for heat and energy. If these are not addressed, the resultant warming is likely to have a number of negative impacts which will reduce the future security of the poor (and the rich as well, but the poor always suffer more as they have less capacity to mitigate risks).

2.7.8 *National level issues*

The anticipated growth in energy demand which developing countries with financial, operational and environmental constraints face are independent of any consideration of carbon emissions. Beyond the issue of greenhouse gases and the possible impacts of climate change, many developing countries are already suffering from severe environmental degradation and negative effects from their energy production. Emissions from the burning of fossil fuels for industry, transportation and power generation are the largest sources of urban air pollution and add particulates, sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and other pollutants. Worldwide, the cities with the poorest urban air quality are in the developing countries; with increasing urbanization and energy production and use, this situation will deteriorate even further if no ameliorative measures are taken. Even the relatively clean resources from the point of view of emissions, such as hydro power, flood agriculture and forest lands, force the resettlement of people, usually the poor, and disrupt their local environment for sustainable livelihoods.

Taking again a specific case from India, this project was to first examine the energy efficiency opportunities in the small foundry and glass sectors in India. In both cases, the current practices which are highly polluting and energy inefficient have drawn attention from the courts for violating local pollution standards and many units are threatened with closure or have closed. Under the circumstances, it was decided to select an alternative sector which is not facing a similar crisis. Clearly, the loss of employment for violations of environmental quality affects poor workers in these industries more than the wealthier consumers.

For all countries, and especially for developing countries, energy and economic development are closely linked; their economic growth, the primary method for eliminating poverty, requires growth in energy services. Policymakers everywhere are concerned that energy services, which are too expensive, will affect employment, growth and development negatively. Both India and Ghana currently have significant energy shortages, in the range of 30-40 percent, unreliable and poor quality of energy infrastructure and production and high inefficiencies. These in turn result in high economic costs because of material waste, low-capacity utilization and investment in standby equipment as a stop-gap measure. In most countries, it is argued that improved production and use efficiencies, promoted and implemented through appropriate policy reforms and technological applications, could reduce total energy use by over 50 percent.

Improving the economic efficiency of energy production and end-use has the potential to allow developing countries to meet their economic growth and improved living standard needs with their own economic, financial, operational and environmental resources. This is a classic “win-win” option in which the economic needs of developing countries would be matched with their environmental needs and also the global need to reduce carbon emissions.

One principal direction to the solutions to the energy dilemma developing countries (and industrialized countries) face is to treat their energy, economic development and growth strategies with environmental problems as interrelated issues and look for more immediate solutions to all three. This calls for increasing the energy efficiency of all energy uses, reducing, where appropriate, the demand for certain energy-intensive uses and generating and transmitting the reduced requirements of energy with the best combination of high technical efficiency, high economic efficiency and low environmental impact.

3. Efficiency, growth and rebound effect[78]

Energy efficiency that is economical makes energy inputs cheaper. Cheaper energy has two distinct effects that cannot be denied. At a micro level, and in the near term, individuals and firms which had been constrained by energy inputs increase their use of energy services and thereby increase outputs and, hence, growth. This will continue until the constraint is not binding.

In sectors and activities where the demand for energy is reduced below the availability or is unconstrained, the energy services obtained would remain constant, would make energy available for other uses and potentially lead to a decrease in energy to GDP.

Over time, on the supply or production side, and more directly relevant for firms, there would be a substitution of energy for other factors of production, which now become relatively more expensive. And this is one of the factors highlighted by Jevons on the coal question, where the increasing efficiency of the steam engine resulted in large increases in its use and hence large growth in the use of the energy from coal. There has been an increased discussion of 'rebound effects' from more efficient use of energy.

[78] The issues of the "rebound effect" have been reviewed by Dimitropoulos, John, 2007.

There are several levels at which the rebound effect can be considered. First at the micro, individual or firm level, evidence suggests that the ‘direct’ rebound effect varies depending on the elasticity of demand, which in turn depends on the nature of the energy service. Until a certain minimum level of services is used, for example, for lighting or space conditioning, there will be some increase in use with a resultant decrease in cost. When the level of energy service is above an adequate level, there need not be an increase in energy use for the same service. But the release of income could then be reinvested in consumption and new production capacity.

One fundamental goal is to promote economic growth and prosperity that is sustainable, which in turn in the case of energy requires decreased emissions. For this to be combined with the reduction of greenhouse gas emissions there will have to be a "decoupling" of economic growth from its environmental impacts or continued and rapid drop in energy intensity. However, the same benefits of efficiency may not apply to ‘indirect’ and ‘economy-wide’ effects as in all cases, an economically and technically energy efficient solution releases income or revenue that can be spent for acquiring additional units of the same energy service or additional units of outputs that require additional energy inputs. Here, several authors suggest that improved energy efficiency may increase energy consumption in the medium to long term, a view that undermines the rationale for energy efficiency as an instrument of climate-related energy policy. The proponents point to evidence from a variety of areas, including economic history, econometric measurements of productivity and macro-economic modelling.

Thus, theory suggests that in the longer term, increased growth with lower GDP to energy intensity may well allow for increased energy consumption and so has no value to resolving the problem of energy waste. However, to date, the evidence base is relatively small, highly technical, lacks transparency, rests upon contested theoretical assumptions and is inconclusive. The paper provides an accessible summary of the state of knowledge on this issue and shows how separate areas of research can provide relevant insights: namely, neoclassical models of economic growth, computable general equilibrium (CGE) modelling and alternative models for policy evaluation. The paper provides a synopsis of how each approach may be used to explain, model and estimate the macro-economic rebound effect, criticisms that have been suggested against each, and explanations for diversity in quantitative estimates.

Data shows that in almost all IEA member countries, energy intensity has fallen by more than a third in 30 years. In particular, there is a school of thought deriving from the work of the nineteenth century economist Stanley Jevons, which argues that while increased energy efficiency at the microeconomic level may lead to a reduction in energy use at the macroeconomic level, it in fact leads to an increase in overall energy use[79].

4. Conclusions

It is worth recalling our comment at the beginning of the paper. The list of topics that have been assigned to this paper occupy a very large set of issues, and within this large boundary, many of the issues interact with one another both directly and indirectly. Given the large number of issues outlined above, most of them cannot be dealt with directly and in great detail here.

This review highlights that certain important questions on energy and growth; between energy and poverty; and energy efficiency and technical change or technology and their drivers have not been posed by researchers and policymakers with sufficient depth and thus many issues remain unresolved. There are also issues such as the fundamental nature of energy and energy efficiency and economic growth, where key pieces of evidence that exist have been ignored. Some of the difficulties arise due to the interdisciplinary nature of the questions raised, but many others arise within the discipline of economics where the causes and factors of growth remain debated and in dispute.

Many difficulties in our understanding have also emerged from the fundamental facts that increased energy use and increased energy efficiency have been one of the primary inputs/drivers of output and economic growth for the entire modern industrialization history of over 200 years, but the increased focus on energy and efficiency have only a history of three decades. It will take time and concerted and ongoing effort by researchers, governments and agencies such as UNIDO to determine some of the ambiguities and also develop a more robust longer term data sets and empirical evidence to drive the new policy frameworks.

[79] This proposition is known as the "Khazzoom-Brookes postulate" after economists Daniel Khazzoom and Leonard Brookes, who independently published papers putting forward this argument in 1979-80.

We conclude that overall, energy efficiency produces multiple “win-win” outcomes as overall increased energy efficiency accompanies technological change that increases the efficiency in the use of both raw materials and energy; thereby, it eliminates or reduces emissions of harmful wastes generated in production; hence, it ensures minimum hazards to human and ecological health for a given level of output; and it drives economic growth and expands employment opportunities. There are now hundreds to thousands of case study examples[80] which are available where “cleaner” approaches produce ‘win-win’ situations for the firms, the economy and the environment. The general conclusion is that in an extremely wide variety of situations, efficiency gains of 50 percent in energy intensity provides high economic gains for firms, with pay-back periods of a few months to a few years. Yet the take-up of such opportunities by firms is relatively slow. While the reasons remain debated and the discussions are extensively covered in the other UNIDO chapters, the facts cannot be disputed.

It is our view that some of the important barriers are institutional, resulting from the nature of the market for environmental technology and services and almost all fall under barriers to technological change and innovation in general. In almost all manufacturing and other sectors there are a range of technologies available which can improve the efficiency of use of energy, which combine not only new machinery and equipment, but also "softer" options such as re-engineering of processes and housekeeping measures which can be implemented with minimal capital costs. Yet the spread of such technologies in developing countries has been relatively slow, and is slower still among small- and medium-sized enterprises (SMEs). This is the challenge for UNIDO and for developing countries.

Energy efficiency is a core issue for security, growth, poverty, local pollution and climate change. It needs to be reframed as such and the world must move beyond “demonstrations” and

[80] Many cases, sectoral studies as well as other references are listed in the UNIDO chapters.

testing of efficiency approaches to longer term and consistent efforts, develop indicators, macro and micro, and promote policy and institutional change in all countries. At the same time, efficiency must incorporate poor people, poverty and access and cannot be defined narrowly. Lessons and analogies from public health and other fields, incorporating inputs from a much wider set of knowledge – beyond engineers and economists – is required to fill the gaps and missing dimensions of political economy, sociology, communications, behavioural studies and others. As we struggle to adjust to a new carbon constraint – unprecedented in history – many old paradigms have to be abandoned and new ones built from the ground up.

Finally, while we believe that energy efficiency also provides a key tool for the transition to a lower carbon economy and for the greater use of renewables, we do agree that much more work is required to determine the extent to which growth can continue with absolute reductions in energy inputs. But at the same time, while the answer to this question will become clearer over time, Khazzoom-Brookes' hypothesis on the rebound effects, while very important, does not negate the role of energy efficiency at least in the near term as a solution to the mitigation of greenhouse gas emissions from energy use.

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