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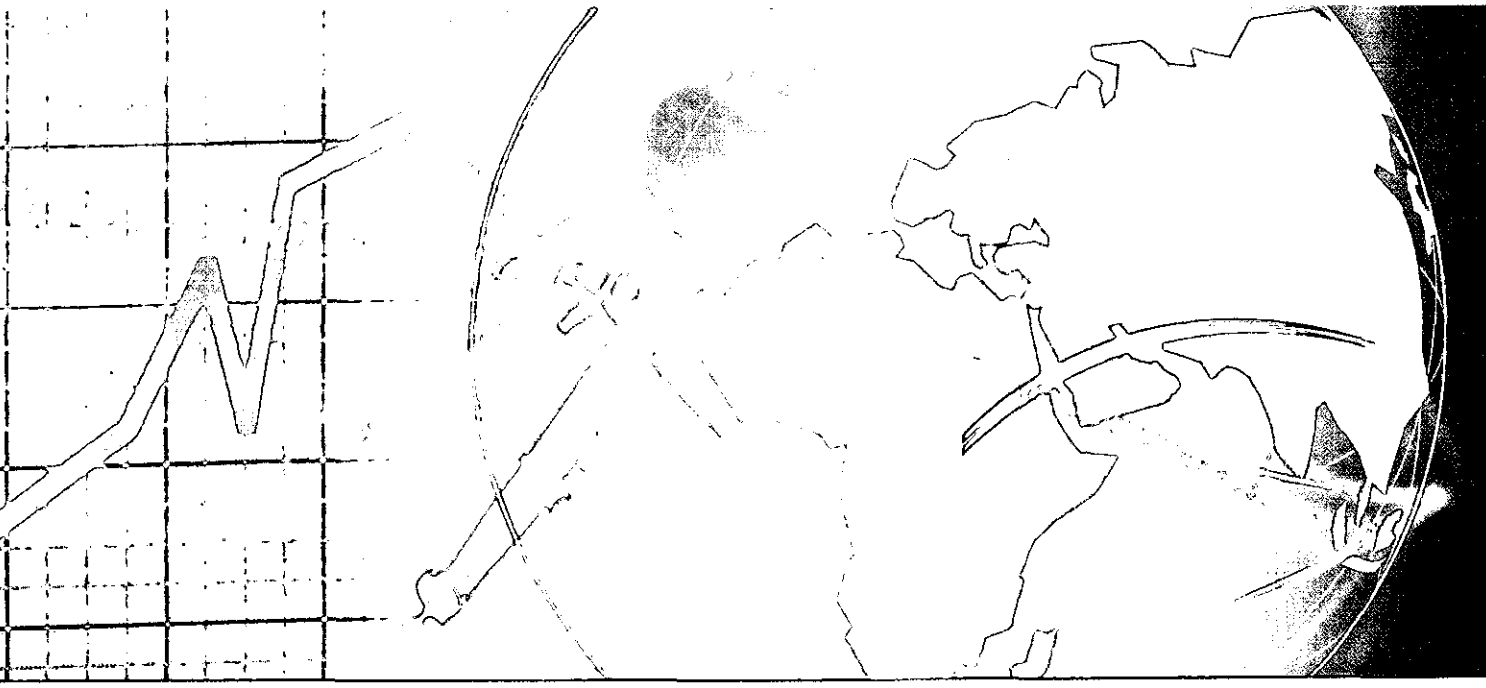

Energy, industry modernization and poverty reduction: a review and analysis of current policy thinking

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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Energy, industry modernization and poverty reduction: a review and analysis of current policy thinking

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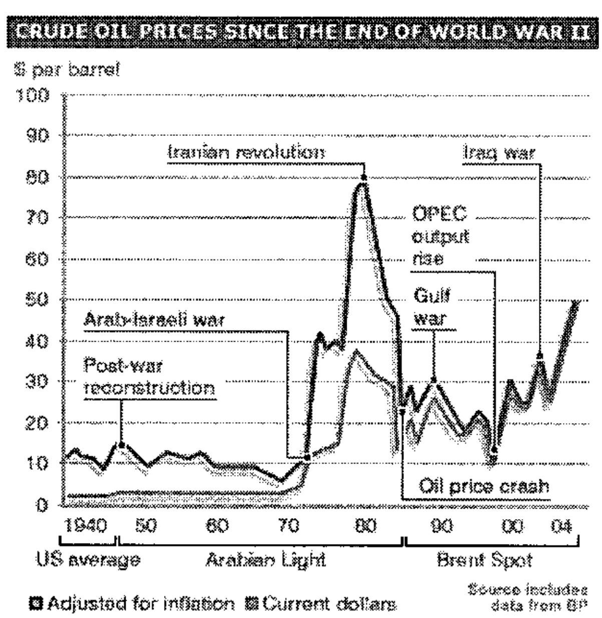
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2007

Disclaimer:

This paper reviews and analyses the variables for policy formulation concerning relationships of energy (its availability, accessibility and use) with economic development and concomitantly poverty reduction. From a policy perspective, this brief undertakes firstly an extensive literature review and analysis of the infrastructure dynamics of energy (especially in its electricity form) within the context of relevant geo-political and economic considerations concerning hydrocarbon sources of energy in relation to development and industrial output. Secondly, the review isolates the key connections, correlation models and statistical significations of the relevant variables. This is in order to address current policy prescriptions aimed at improving the essential conditions of energy availability, accessibility and consumption for the poor. Thirdly, it looks at relevant issues regarding international community technical co-operation assistance to developing countries in the light of policy thinking. It addresses not only the technical aspects, but also the managerial aspects of assistance related to energy and modernisation. Finally, the constraints on policy craft and areas for further policy research and analysis are addressed.

Hydrocarbons (oil and gas) dominate the energy equation and the conversion into electricity, as well as fuel for industrial transformation. More importantly, electricity's share of world total final energy consumption, which stood at 18 per cent in 2000, is expected to increase to 22 per cent by 2030. In this respect, deliberations on energy need to be mindful of the long-term volatility of oil which is illustrated below.



For hydrocarbon-rich developing countries, the economics of oil provides opportunities for population-wide economic development arising from the windfall of higher prices; and calls for greater emphasis to be placed on economic, institutional and structural stability in development in order to lower risks and avoid threats of disruption to oil supplies. Simultaneously, it could lead to more robust bargaining power in the hands of élites in developing countries. The relative merits of different policy choices regarding energy and industrial modernisation are best viewed with the benefit of certain stylised facts. These facts, which relate to the availability and distribution of access to energy, and their relation to economic development, are briefly as follows:

(i) Some 25 per cent of the world's population have no direct access to electricity, and by 2030 about 1.4 billion people will lack electricity.

(ii) Approximately 80 per cent of the world's rural population does not have access to electricity.

(iii) Between now and 2030 some 2.4 to 2.6 billion people will continue to rely on traditional biomass for energy to cook and heat.

(iv) Africa generates only 4 per cent of the global electricity supply.

(v) About 500 million Africans are without modern energy.

(vi) There is a strong positive correlation between direct access to electricity and per capita income in terms of the percentage of population living on or below US$2 per day.

(vii) There is a matrix of links between energy and development. However, most developing countries often lack the institutional managerial capability and technological capacity to articulate, cohere and calibrate accurately the specifications of these links.

(viii) The comparative structures of energy consumption in the world and Africa show marked differences with biomass accounting for 14 per cent and 59 per cent, electricity accounting for 16 per cent and 4 per cent, and petroleum accounting for 44 per cent and 25 per cent, respectively.

(ix) There are strong and proven empirical positive correlations between energy and economic growth, between energy and economic development, and between electricity use and economic development.

(x) There is a strong link, and negative correlation, between energy use and poverty -- in so far as no country has managed to substantially increase the rate of poverty reduction without increasing the use of energy (usually in the form of electricity).

(xi) Changes in quality, that is, efficiency gains from transitions, in energy services drive general economic productivity.

(xii) Total factor productivity growth is positively correlated with energy use.

(xiii) While infrastructure is but one dimension of the development challenge, its impacts are among the most important.

(xiv) The literature on energy and development tends to focus on how demand for energy, and its services, are induced by economic development rather than how energy (and electricity) use produces economic development.

In relation to the last stylised fact, it is important to note that, in terms of input factors, as technical progress increases, the share of total value added accounted for by electricity increases, so electricity-using productivity growth results.

The empirical literature on energy and electricity, their economically complex relations to modernisation, industrialisation and poverty reduction conveys a consistent message. That message confirms the physical, crucially important and central place of thermodynamic laws in economic activity. And statistically, the literature indicates that energy use *causes* gross domestic product (GDP) growth. Furthermore, national leadership and necessary political will are vitally important to enable success in government efforts to electrify countries. Electrification of countries has historically taken around 40 to 60 years of continuously incremental investment, as well as industrial maintenance. Crucially important is the finding that the elasticity of the policy variable electricity/energy ratio is higher in industrialised countries compared to developing countries; and therefore, increasing the ratio has a greater effect on the GDP growth in an industrialised country than a similar increase in the ratio on developing country GDP. The key policy implication of this relationship is that developing countries have to work harder in terms of the systemic organisation and information required to realise the positive externalities of electricity use. The most significant policy variables are listed in the following table.

Rank	Dependent Variable (V_d)	Independent Variable (V_i)	Policy Effect of V_i on V_d
1	Electricity access	Decrease in rural households*	7.3 times more
2	Electricity access	Decrease in households below poverty line	1.8 times more
3	Electricity access	Increase in household income per month by US$100	1.3 factor increase
4	No. of households below poverty line	Electricity improvement	0.4 less probable
5	No. of households with less than US$1/day income	Electricity improvement	0.2 less probable
6	GDP index	Energy use	0.9 per cent increase
7	Non-farm employment	Increase in rural electricity consumption per rural worker	0.4 per cent increase
8	Non-farm employment	Increase in rural electricity consumption	0.2 per cent increase
9	Poverty reduction	Increase in rural power network investment by US$133,000	500 less poor people
*This is taken to be the same as an increase in urbanisation.			

The relative success of the international community's policy advisory and technical co-operation assistance, and specifically UNIDO's work, in germinating and taking root in the institutions of the assisted country depends, to a large extent, on whether successive host governments have the requisite long-term economic vision and planning for the future; whether they can establish, articulate and sustain an efficient incentive system economy-wide; and whether they have the strategic intent with respect to financing energy infrastructure in a sustainable manner. Given these preconditions, the possibility of policy advisory and technical co-operation assistance contributing to socio-economic development is high; without them it is practically non-existent.

UNIDO's catalytic inputs to the energy sector policy reform process are depicted in broad terms of policy advisory and technical co-operation assistance, investment, technology and functional disciplines that are vital to industrialisation given the thermodynamic basis of economic and industrial activity. In this regard, the negative correlation of oil-rich endowment to energy use is of particular importance to the oil exporters of sub-Saharan Africa (SSA) and elsewhere. In this respect, industrial strategies to assist in diversifying (counter intuitively) their hydrocarbon export economies are crucial to assist in safeguarding the legacy of hydrocarbon endowments for future generations.

With reference to hydrocarbon-rich SSA countries, UNIDO's continuing role in delivering technical assistance would need to focus on enabling the energy mix to undergo transformation over the long-term. Thus, the transition towards more efficient forms of energy can reinforce enterprise upgrading, national cleaner production programmes, foreign direct investment and technology promotion. Also important is the need for UNIDO to support developing countries to bring science, technology and innovation and their knowledge-based institutions into the mainstream of policy thinking on energy for development. UNIDO's support to national systems of innovation on a continual basis is vital for accelerating technology diffusion. In all this, an essential balancing act is necessary. This concerns the difficult trade-off between increasing energy use in a variety of efficient forms and greenhouse gases, pollution and climate change. This trade-off carries transaction costs which have to be paid for. To lower transaction costs, UNIDO's technical expertise is called for. The message is simple - there is no incidence of economic development and growth without expanding the use of increasingly efficient forms of energy. This may seem blindingly obvious, what is not so easy to identify is the different gearings that different energy variables have to GDP growth, and its proxies. This policy brief endeavours to assist in this identification.

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List of Tables and Figures

List of Abbreviations

ADB	Asian Development Bank
DfID	Department for International Development, United Kingdom
ESMAP	The Energy Sector Management Assistance Programme
GEF	Global Environmental Facility
HDI	Human Development Index
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
JIBC	Japan International Bank for Cooperation
LDCs	Least Developed Countries
MDGs	Millennium Development Goals
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
PATA	Policy Advisory, Technical Co-operation and Assistance
R&D	Research and Development
SMEs	Small and Medium Sized Enterprises
SSA	Sub-Saharan Africa
TFPG	Total Factor Productivity Growth
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
USAID/SARI	U. S. Agency for International Development/South Asia Regional Initiative for Energy

Abstract

This paper discusses the relationships of energy in terms of its availability, accessibility and use, and economic development and concomitantly modernisation and poverty reduction, and development policy formulation. The pertinent literature is extensively -- but not exhaustively -- reviewed for the purpose of disclosing the economic characteristics of energy relationships, as well as the most significant variables in the interlinkages of energy, particularly electricity, and economic development. These variables may be subjected to policy craft, and hence they form the basis for multilateral agency -- including UNIDO -- policy advisory and technical co-operation assistance to developing countries and countries with economies in transition. The review and analysis are set appositely within the context of the long-term increasing volatility of the global energy outlook, its security aspects and broad geo-political implications for development. The statistically significant variables isolated are described in terms of the gearing, or leverage, they have to the various proxies for economic development and growth.

The review and analysis together confirm the centrality of energy, in its progressively more efficient forms, within the process of modernisation and industrial transformation. More importantly, the analysis and significant variables in concert provide the perspective that the processes involved in the so-called energy transition (i.e. from low efficiency to higher efficiency forms and sources) are long-term and require persistent and continuously incremental capital accumulation. Furthermore, these processes demand a certain level of national managerial capacity and capability for dealing with technology, information and the organisation of systems. The place of UNIDO's enabling services in the matrix of the links between energy and development is articulated with respect to policy advisory and technical co-operation assistance not only in building up the capacity and capability of developing countries and economies in transition, but also in policy regarding reforming the energy sector. Reference is made to multilateral inter-Organizational relations in the context of UN-Energy and the MDGs.

Preamble

This paper reviews and analyses the variables of policy craft and policy formulation concerning energy (its availability, accessibility and use) relationships with economic development and concomitantly poverty reduction. It is apt at a time when, through a combination of circumstances as varied as geo-politics, geology and geography, investment (or lack of it), hurricanes,[1] and petroleum industry cycle and demographics, apprehension of an international energy crisis is growing. And the price of oil -- the basis of the energy industry -- is hitting record levels.[2] The subject matter is necessarily broad, and it is therefore important to indicate, at the outset, what this paper does and does not cover. Energy relationships are at the heart of the development debate, and are crucial for the achievement of the MDGs. This paper does not review economic development (or its models) per se. It does not account for the different modalities of development and path dependent trajectories for different economies. Furthermore, while it does not address issues pertaining to specific types of energy use and climate change, issues germane to energy use, energy prices, and sustainability are touched upon briefly.[3]

Definitions and statistics on hydrocarbons are not addressed directly for obvious reasons. This is partly because of stylised facts on energy and poverty, and the abundantly available data on global income distribution. And partly due to the Human Development Index, and a plethora of other 'development indices',[4] that indicate the relative performance of various countries across a range of variables. This paper takes as given the equivalence between modernisation and economic growth; and that the income distribution and growth bifurcation between the industrialised countries and developing

1 See Special Report 'Hurricane Katrina's Impact on the US Oil and natural gas Markets', Energy Information Administration, Official Energy Statistics from the US Government, 1 September 2005.

2 See 'Fears grow of energy crisis after hurricane', *Financial Times*, 1 September 2005, p.1, for a view of how the combination of circumstances could temporarily unravel energy supplies.

3 This is primarily because at the macroeconomic level, the relationship between energy use and sustainability is subject to highly complex non-linearities and asymmetries. For example, the various forms of the "Rebound effect" (Binswanger, 2001; Brookes, 1990; Lovins, 1988; Khazzoom, 1980) postulate that declining energy intensities, or use, can cause higher energy consumption as economic surplus thus generated is used to create other goods and services with differentiated energy efficiencies.

4 See A. T. Kearney, 2004, *FDI Confidence Index*, Global Business Policy Council, volume 7; A. T. Kearney, 2004, *A. T. Kearney's 2004 Offshore Location Attractiveness Index: Making Offshore Decisions*, Chicago; Fraser Institute, *Economic Freedom of the World: 2004 Annual Report*, Vancouver; Heritage Foundation, 2005, *2005 Index of Economic Freedom*; IMD, 2003, *The World Competitiveness Yearbook 2003*, Geneva; Transparency International, *Framework Document: Background Paper to the Corruption Perceptions Index*, Passau; UNDP, 2003, *Human Development Report: Millennium Development Goals: A compact among nations to end human poverty*, New-York; UNIDO, 2002, *Industrial Development Report 2002/2003: Competing through Innovation and Learning*, Vienna: UNIDO; WEF, 2000, *Global Competitiveness Report*, Geneva; World Bank, 2005, *Doing Business in 2005*, Washington D.C.: IBRD/World Bank/OUP.

countries[5] is indicative of the relative energy use intensities [Temple (1999); Durlauf and Quah (1998)]. It uses the UNIDO classification of industrialised and developing countries [UNIDO (2002)]. Finally, for ease of reference and argument, the terms energy and electricity (while not strictly equivalent economically or physically) are used interchangeably not only because fossil fuels -- and primarily hydrocarbons (oil and gas) -- dominate the energy equation and the conversion into electricity, as well as fuel for industrial transformation[6] [IEA (2002)], but also because electricity's share of world total *final energy consumption, which stood at 18 per cent in 2000, could increase to 22 per* cent in 2030 [IEA (2002)].

Rather, from a policy perspective, the paper undertakes first, an extensive literature review and analysis of the infrastructure dynamics of energy (especially in the form of electricity), in terms of relevant geo-political considerations concerning hydrocarbon sources of energy in relation to development and industrial output. Secondly, it attempts to isolate the key connections, correlation models and statistical significations of the relevant variables. This is in order to address current policy prescriptions aimed at improving the essential conditions of energy availability, accessibility and consumption for the poor. Thirdly, it looks at relevant issues regarding the international community's technical co-operation assistance to developing countries in the light of policy thinking. It also addresses both the technical and managerial aspects of assistance related to energy and modernisation. Finally, the constraints on policy formulation and areas for further policy research and analysis are addressed.

The scope of this paper is, therefore, strictly limited to the relationship between energy and industrial output in relation to poverty reduction (or GDP growth). The underlying logic is that of the quintessential and principle thermodynamic dimensions of human economic activity organised across complex societies. The frame of reference for the literature review,[7] though not exhaustive, basically covers the period 2000-2005 and includes the following keywords: energy, electrification, economic development, infrastructure, poverty, public spending, and policy reform. However, seminal references prior to 2000 have also been reviewed. This paper does not analyse UNIDO's technical

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5 For brevity, developing countries include countries with economies in transition.

6 The United States, the world's biggest consumer of oil at approximately 22 million barrels per day (2004), converts oil into use as transportation (67.8 per cent), industrial fuel (12.7 per cent), industrial feedstock (11.7 per cent), buildings (7.7 per cent). According to the Financial Times, 'Global Crude Supplies', 5 August 2005, p.6. China, the next biggest consumer, uses approximately 6.5 million barrels per day (2004).

7 Over 250 empirical journal articles, academic and policy papers, reports, book reviews and media reports have been reviewed. The number of Internet searches is approximately 300. The material included case studies, general equilibrium and regression models.

co-operation activities under the Global Environmental Facility (GEF). These are amply referred to in various reports, including the UNIDO Annual Report 2004,[8] which indicates the range of projects [UNIDO (2005)].

The remainder of the paper is structured as follows. Section 1 -- Introduction -- presents a précis of stylised facts concerning global energy in terms of geo-political security, resources availability and access. It draws out the development implications and reveals various 'gaps' while addressing initially some of the pertinent issues of international community policy coherence in matters related to energy. This section also presents the stylised economic facts on energy use and output.

Section 2 -- Literature Review -- covers the various aspects of industrial logic pertaining to energy and, in referring to empirical evidence from various studies (cases, panel data, etc.), presents the significant factors and variables for policy attention. The evolving policy shift related to the provision of infrastructure for development is touched on, as are policy choices and the role of government and the public sector. Examples from the industrialised (OECD countries) and developing countries are used to illustrate the complex policy choices and implications.

Section 3 -- Correlations and Models of Energy Use and Economic Development -- captures concisely the statistical relationships between the key factors and variables. The impact of variables on modernisation and poverty reduction is reviewed for policy formulation. Attention is also drawn to the economic implications of hydrocarbon resource endowments.

Section 4 -- Policy Advisory and Technical Co-operation Assistance -- addresses the role that is available for the international developmental agencies (including UNIDO) to play in assisting developing countries. Special attention is given to sub-Saharan Africa to illustrate the link between energy and development vectors and the MDGs. This section also addresses the constraints on viable policy action.

Section 5 -- Concluding Remarks -- brings together the key lessons for policy action as guides for the developing countries. It suggests areas for augmenting the current state of knowledge regarding energy and development.

8 See pp. 58, 80, 81, 137 and 138 of UNIDO Annual Report 2004.

Section 1 – Introduction

Conventionally, in matters related to energy, geo-politics looms large [Parra (2004); Pauwels (1996); Yergin (1991, 1983); Yergin and Hillenbrand (1983)] and due to structural adjustment in the global economy [OECD (2002)], the geo-politics of oil dominate the current debate on energy because of issues associated with securing supplies [IEA (2004, 2005); Mitchell (2003)]. And in this debate, the large energy consumers -- especially the OECD countries and the United States, but increasingly China[9] and India[10] -- wield significant influence in shaping energy outcomes [Mitchell (1996)]. In particular, economic globalisation and concomitant global political interdependence are having profound effects on the geo-politics of energy. Increasingly foreign policy is crafted to secure energy supplies [Mitchell (1996)] in a world where, through a combination of geology and lack of investment,[11] converting hydrocarbon reserves into available supply is estimated to require an investment as high as US$16,000 billion between now and 2030 [IEA (2004)].

Implications for energy security concerns and resource availability in developing countries could lead, on the one hand, to greater emphasis in development on economic, institutional and structural stability in order to lower risks and threats to oil supply. On the other hand, the lack of investment, by increasing global insecurity, in the short- to medium-term, could lead to increased militarisation of foreign policy postures[12] by the great powers [Mitchell (2003)]. Simultaneously, it could lead to more robust bargaining power in the hands of élites in developing countries,[13] and global, or rather the

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9 See Jeffrey Bader and Flynt Leverett, 'Oil Politics, the Middle East and the Middle Kingdom', *Financial Times*, 17 August 2005, p. 11 and Fred Bergsten, 'A Clash of the Titans Could Hurt Us All', *Financial Times*, 25 August 2005, p. 11 for an analysis of "the rapid, almost unfathomable growth in China's energy demand" and geo-political implications for oil security, including a potential new 'Scramble for Africa' that could arise because of the clash of energy security interests and emerging challenges to hegemony.

10 According to The Economist, "Oil and the global economy: counting the cost", "India and South Korea use more oil per dollar of GDP today than they did in the 1970s." (*The Economist*, 27 August 2005, p. 57)

11 Current concerns about the price of crude oil are but one manifestation of the problem of energy security. See 'Big Oil Warns of Coming Energy Crunch', *Financial Times*, 5 August 2005, p. 6 for an indication of how the era of relatively cheap oil is coming to an end and in which the large economies are vulnerable to interruptions in oil supply. There is also increasing concern over the reliability of data on hydrocarbon reserves and reservoir decline rates which is worrisome (M. Carr and T. Couter, 'Shell Cuts Oil and Gas Reserves for the Fifth Time', *Energy Bulletin*, 5 February 2005, Bloomberg; and Talking Point, On Oil, BBC World Service, 28 August 2005).

12 See BBC News, US Targets Sahara Militant Threat, 14 January 2004 and Secretes in the Sand, 8 August 2005, and 10 August 2005; and 'Oil Companies Positive About Mauritania', *Financial Times*, 5 August 2005, p. 6 for an analysis of the increasing confluence of geo-politics of oil and security.

13 See Mark Moody-Stuart, 'A Warning for the World Bank', *Financial Times*, 4 May 2005, p. 15; and Alan Beattie, "Oil price rise 'Means Bigger Corruption Threat for Countries'", *Financial Times*, 27-28 August

international community's, tolerance of poor governance. Such tolerance would tend to militate against the opportunities for population-wide economic development arising from the windfall of higher oil prices. There are also serious questions concerning the sources and forms of finance for the much-needed investment in the oil industries of developing countries.

In sharp contrast to the perhaps unguarded[14] optimism of the late 1990s that projected consensually an oil price of below US$25 per barrel (1999 prices) to 2010 (and less plausibly so to 2020) [Gately (2001, p. 26)] there are serious risks in the energy outlook [Yetiv (2004); Joskov (2003, pp. 21-22); Smil (2003); Ghalib and Knapp (2004)]. These are increasingly manifest as difficult trade-offs outside the market process involving security and geo-political uncertainties, technology and national policy [Greenspan (2005)].

There are crucial short- and medium-term risks in the energy outlook and concern over securing supplies is steadily moving up the international agenda,[15] not least because political instability in oil-exporting developing countries could drive the oil price to escalate towards US$160 per barrel.[16] This scenario holds considerable opportunities for resource-rich developing countries to accelerate their economic development, but poses severe threats for resource-poor developing countries [World Bank (2005a)]. It also raises considerably the stakes in the geo-political 'great game' of winning energy supplies[17] to fuel economic development and growth.

Such acute concerns point to the central, but highly complex, link between increasing energy use and increasing economic output, and hence socio-economic advances in quality of life indices [Patterson (2005)]. While energy intensity is set to continue declining as a function of innovation and increases in total factor productivity

2005, p. 4 for implications of translating a country's mineral and oil wealth into economic wealth in a way that reduces poverty in the face of soaring oil prices.

14 Founded on a US$20 – US$40 price range for oil that remained unchanged between 1980 and 2005 (*Financial Times*, 28 January 2003, p. 13) and assuming faster non-OPEC supply growth, slower oil demand and "price-responsiveness of oil demand and non-OPEC supply" (Gately, 2001, p. 26) based on moderate output.

15 See Siobhan Hall, 'EU Works on Anti-Terrorist Energy Security Plan', *Energy Economist*, No. 286, August 2005, p. 22; and Markandya et al. (2005) for analysis of the increasing geopoliticisation of policy related to sources of energy.

16 According to a recent simulation exercise, Oil Shockwave Simulation, performed by the U.S. National Commission on Energy Policy, and the Advocacy Group, 'Securing America's Future Energy' reported in the *Financial Times*, 5 August 2005, p. 6. This scenario could be compounded by serious doubts over the reliability of 'proven hydrocarbon reserves' (Adam Porter, 'How much oil do we really have?', BBC News Online UK Edition, 15 July 2005).

17 See Paul Reynolds, 'Oil and Conflict – A Natural Mix' (BBC News Online UK Edition, 20 April 2004) for developments in the Caspian Sea region.

growth (TFPG), primary world energy demand is projected to expand by 60 per cent by 2030 at an annual rate of about 2 per cent [IEA (2004]. Energy consumption patterns are noteworthy due to their geo-political implications. The change in demand between 1980 and 2002, in terms of million barrels per day of oil, for the Republic of Korea, India, China and Brazil is astonishing at +306 per cent, +240 per cent, +192 per cent and +88 per cent, respectively.[18] Fossil fuels will predominate, and continue to dominate the expansion in demand and will account for some 85 per cent of the increase and hydrocarbons will continue to remain the single most strategic source of fuel in the energy mix.[19] Furthermore, from a security perspective, 20 of the world's top 40 per capita petroleum producers could be viewed as potentially being seriously prone to political-economy instability [Myers (2005)].

We live in a world of increasing energy demand and increasing volatility with respect to growing international trade and risks in globalisation that emerge from the geography of oil.[20] And, at national economy level, how much oil a county has is of crucial importance to development. In relation to this, there appears to be a critical cut-off parameter[21] above which prospects are good and below which non-OECD producer countries fair poorly. The increased demand for energy from now to 2030 will, therefore, be dominated by oil and electricity, with the latter requiring about US$10,000 million worth of investment at current prices. Unfortunately, renewable energy will constitute only some 6 per cent of electricity demand[22] [IEA (2004); Odell (2004)]. Furthermore, approximately 66 per cent of the increase in global energy demand will be from developing countries as the link between energy consumption and output leads to higher levels of economic development, which in turn increases energy demand.

18 See Comment and Analysis, Oil Market, *Financial Times*, 17 May 2004, p. 11.

19 The distribution of energy intensity (that is, relative oil intensity) across countries is highly asymmetric with China and Africa, each more than twice as energy intensive as the OECD, while India is nearly three times as much, in terms of oil consumed per unit of GDP (See Comment and Analysis, Oil Market, *Financial Times*, 17 May 2004, p.11).

20 See George Magnus, 'The World Is Heading for A Shock Over the High Price of Oil', *Financial Times*, 16 August 2005, p.11 for analysis of the oil supply-demand imbalance and the implications for geo politics. Approximately 26 million barrels of oil pass through the two strategic straits of Hormuz in the Arabian gulf and the straits of Malacca in Southeast Asia every day; equivalent to slightly more than the daily consumption of the United States. A number of international territorial disputes can be traced directly to the potential for oil discovery.

21 According to Myers (2005) the relationships between oil, poverty and security shows the cut-off range to be between 20 and 50 barrels per capita per annum. Below this level, revenue streams are insufficient to seriously reduce poverty levels but enough to damage the non-oil sector of the economy via inflated exchange rates, group rivalry for power, volatility of public spending and maintaining poor governance.

22 The concomitant of this is that declining per capita carbon emission is unlikely to be realized across the board in the majority of countries (Lanne and Liski, 2004).

Securing hydrocarbon energy supplies will be increasingly centred on developing countries[23] in which the level and stability of institutional development is questionable [Thomsen (2005)]. There are therefore significant 'gaps' concerning energy in general and oil in particular. Governments need to address these issues also in terms of the international agenda of achieving the MDGs [UN-Energy (2005)].

The relative merits of different policy choices regarding energy and industrial modernisation are best viewed with the benefit of certain stylised facts, which relate to the availability and distribution of access to energy, and their relation to economic development as follows:

(i) Some 25 per cent of the world's population have no direct access to electricity, and by 2030 about 1.4 billion people will be without electricity.

(ii) Approximately 80 per cent of the world's rural population have no access to electricity.

(iii) Between now and 2030 some 2.4 to 2.6 billion people will continue to rely on traditional biomass for energy to cook and heat.

(iv) There is a strong positive correlation between direct access to electricity and per capita income[24] in terms of the percentage of population living on or below US$2 per day [IEA (2002)].

(v) There is a matrix of links between energy and development [OECD (2003/2004), p. 43]. However, most developing countries often lack the institutional managerial capability and technological capacity to institutionally articulate, cohere and calibrate accurately the specifications of these links.[25]

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23 While the Middle East continues to dominate supply for the United States, the diversification of risk means that the United States is increasingly reliant on the West Africa–Gulf of Guinea region as a strategic supplier of crude oil and natural gas.

24 This is also expressed in terms of positive correlations between commercial energy use per capita and GDP (at purchasing power parity) per capita; and between per capita energy consumption and Human Development Index (UN-Energy, 2005).

25 For example, whereas electricity losses as percentage of supply in 2001 averaged less than 10 per cent for OECD countries and the world, the figure for Africa was about 12 per cent, Latin America 18 per cent, Asia 19 per cent. For individual developing countries, the average ranged from about 5 per cent for Zambia to over 45 per cent for Congo with most developing countries averaging well above 10 per cent [OECD (2003/2004), p.44].

(vi) The comparative structures of energy consumption in the world and Africa show marked differences with biomass accounting for 14 per cent and 59 per cent, electricity accounting for 16 per cent and 4 per cent[26], and petroleum accounting for 44 per cent and 25 per cent, respectively.[27]

(vii) There are strong and proven empirical positive correlations between energy and economic growth [Stern and Cleveland (2004)], between energy and economic development [Toman and Jemelkova (2003); Schurr (1982)], and between electricity use and economic development [Ferguson, Wilkinson and Hill (2000)].[28]

(viii) There is a strong link and negative correlation between energy use and poverty – in so far as no country has managed to substantially increase the rate of poverty reduction without increasing the use of energy usually in the form of electricity [Saghir (2005)].

(ix) Changes in the quality, that is, efficiency gains from transitions in energy services drive general economic productivity [Schurr (1984)].

(x) TFPG is positively correlated with energy use [Murillo–Zamorano (2005, p. 81)].

(xi) While infrastructure[29] is but one dimension of the development challenge, "its impacts are among the most important." [ADB/JIBC/IBRD (2005, p. xxi)].

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26 See Electricity in Africa: The Dark Continent, The Economist, 18th August 2007, p. 34 for an analysis of the power shortages that have become the biggest brakes on development.

27 See Stephen Karekezi, 'Options for Addressing the Nexus of Energy and Poverty in the Framework of NEPAD', African Energy Policy Research Network (AFREPEN), No. 298, April 2002, for the analysis showing that apart from South Africa and Zimbabwe, most African countries have yet to achieve 50 per cent of urban and rural electrification and most are between 10 per cent and 30 per cent for urban access to electricity.

28 These three relations should not be taken as academic or as tautological. Pedantic attention to the terms is requisite first because econometrically the proximate sources of growth (investment in physical capital, human capital, R&D) leave open the question of how important energy is as a *causal* factor in development. Secondly, because energy infrastructure development itself is subject to opportunity costs of scarce capital.

29 Transport, water, sanitation, power, gas, telecommunications systems and services.

(xii) *The literature on energy and development tends to focus on how demand for energy, and its services, are induced by economic development rather than how energy (and electricity) use produces economic development*[30] [Darmstadter, Dunkerley and Alterman (1979)].

In relation to the last stylised fact, it is important for the discussion to refer to the extent to which, in terms of input factors, growth in productivity is dependent on the use of electricity [Jorgenson (1981)]. As technical progress increases the share of total value added accounted for by electricity, so electricity-using productivity growth results. This concept not only reflects the changing nature of energy as an input factor value evolving with technological change, but also that of the relationship between productivity growth and input factor prices [Jorgenson (1984)]. Electricity, in its "energy-saving role" [Rosenberg (1998, p. 22)] has accounted for most of the growth in energy use during the twentieth century. For example, in the case of the United States, electricity's share of total energy use increased from under 5 per cent in 1900 to 40 per cent in 1985, a rise of some 700 per cent. In contrast, energy intensity dropped by 77 per cent over the 85-year period. Rosenberg (1998) correctly links electricity with industrial power[31] and notes "If we ask the question: which feature of electrification has had the most pervasive effect on industrial economies ... ?, the answer would have to be ... the widespread use of electrically-powered machinery which, ... played a major role in the growing recourse to mass production technology." [Rosenberg (1998, p.13)]

The stylised facts, and the gaps between energy 'haves' and 'have-nots' attest to the vast international technical assistance and policy advisory efforts aimed at redressing the imbalances.[32] The technical assistance tends to focus on infrastructure provision and the policy advisory aspects to these efforts, and essentially cover sector reforms aimed at improving efficiency and quality through various sequential combinations of public ownership, restructuring, markets and privatisation [OECD (2003/2004); World Bank

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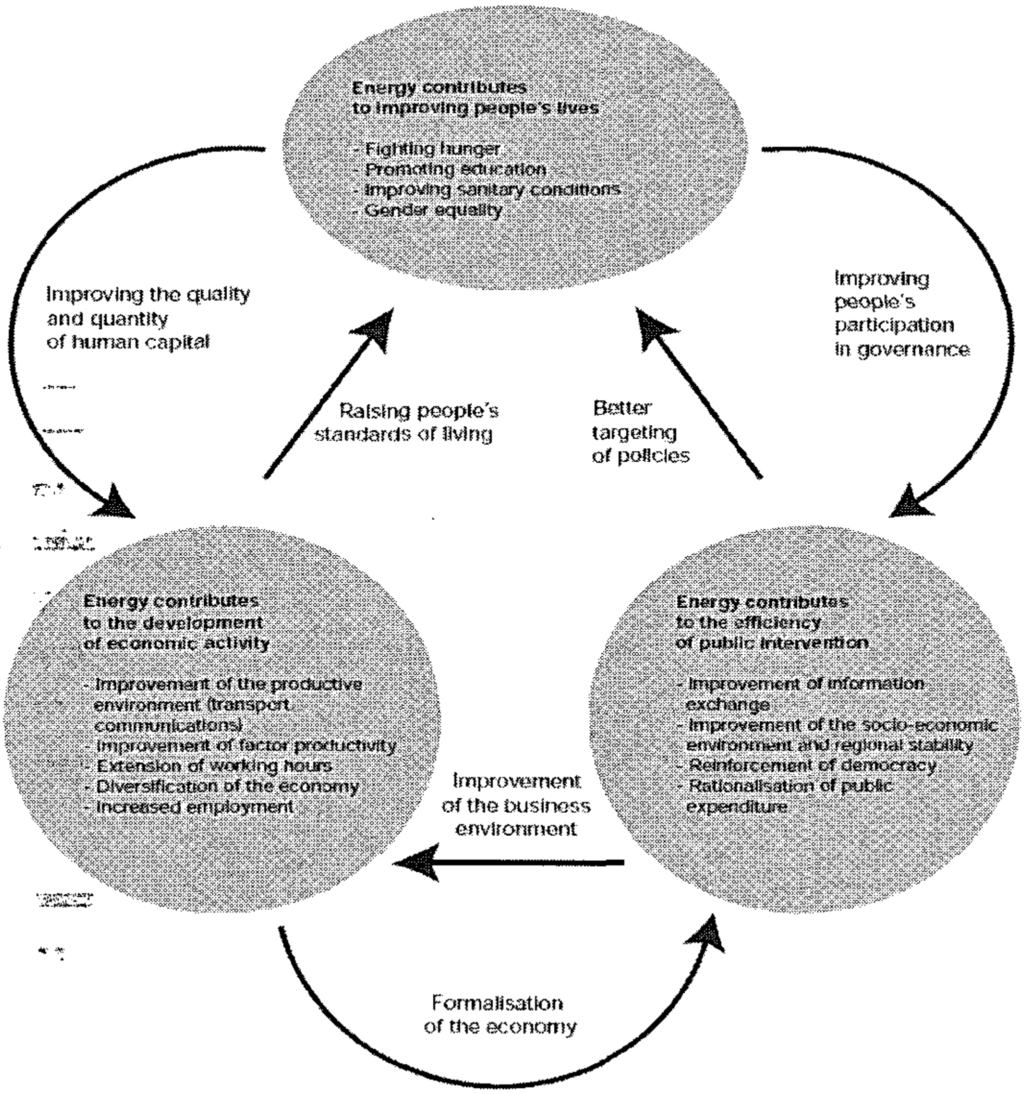
[30] The important question is not how developing societies use energy, rather how energy-using societies develop. And key to this appears to lie in the sequential transition in the form of energy usage.

[31] It is the inherent ability of electricity to enable the immense variety of automatic precision and processing in industry, which is a crucially important and fundamental to the policy craft required.

[32] In 1983, the Energy Sector Management Assistance Programme, (ESMAP), was founded jointly by the UNDP and the donor community. It is directed by the World Bank and is aimed at promoting the role of energy in poverty reduction and economic growth in an environmentally responsible manner. It produces the Energy and Development Report. In 2004, the UN-Energy was formed as the principal interagency mechanism to ensure coherence in the United Nation's response to the resolutions of the 2002 World Summit on Sustainable Development, the achievement of the MDGs and its links with energy availability access and use. In particular, UN-Energy supports the Johannesburg Plan of Implementation in matters related to energy.

(2005b)]. More often than not, these reforms are accompanied by measures which attempt to protect the poor during reform so that the costs of structural adjustment are not shouldered disproportionately by low-income groups in society.[33] The matrix of mutually reinforcing links between energy and development illustrated in figure 1 below serves as a 'lens' for looking at key policy indications and insights from the literature.

Figure 1. Matrix of links between energy and development



Source: OECD, African Economic Outlook (2003/2004).

Figure 1 poses the testing question – what should come first in the policy sequence (and implementation)? An adequate response not only has to reflect the level of policy analysis from the meta- to the firm-level. It also has to reflect the particular developmental stage of the country (or region) in question. However, given the findings

[33] See case study on subsidizing rural electrification in Chile, chapter 9, in Energy Services for the World's Poor (Energy and Development Report 2000, ESMAP, World Bank, pp. 76-82, Washington D.C.).

in the literature, it is apparent that energy (electricity) availability, access to and use in the formalisation of the economy -- through the different phases of the energy transition -- are the precursors.

Section 2 – Literature Review

The literature on energy and electricity, their economically complex relations to modernisation, industrialisation and poverty reduction is vast. The field is also complicated by the related literature on infrastructure and the synergies of development and growth inherent in different combinations of infrastructure.[34] Even so, it is evident that a consistent message runs through all the literature. The message confirms the physical, crucially important and central place of thermodynamic laws in economic activity [Patterson (2005)]. In other words, all activity, in this case especially industrial transformational activity, requires energy. Therefore energy, in one form or another, is ever present as the essential and first factor of production [Stern (2000)]. Furthermore, based on the premise that human development is an information-generating experience, energy is necessary to extract information from the environment. And progressively, the more efficient the energy (and its fuel source), the more efficient the extraction of knowledge from the environment and hence the greater the advance of human experience [Stern and Cleveland (2004)]. However, this is not possible without accumulated knowledge [World Bank (1999)]. This relationship has profound implications for the nexus between energy-industrial modernisation-poverty reduction.

First, it is the level of information and organisation embodied in energy sources and energy technologies that determine the role energy plays in industrial activity. Secondly, different energy vectors (the path dependent structures of technical systems for the distribution, logistics and transmission of energy as well as the supporting services) have different productivities [Rosenberg (1983)]. Thirdly, it is likely that the electricity system is the most successful technology to date for delivering energy [Patterson (1999)]. It is for these reasons that the governments of industrialised economies have invested so much time, finances and effort to electrify their countries. In this regard the electrification of Russia, the United States and Europe, in which the

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34 It is possible to discern literature on electricity and energy linked to poverty reduction, economic growth linked to energy, infrastructure linked to poverty reduction and economic growth, and government and energy.

role of government[35] and its bureaucracy[36] was central to the whole process, is of special significance [Bradley and Fulmer (2004); Bradley (1996); Coopersmith (1992); Hughes (1993)]. The respective processes point to the crucial importance of political vision and will, and the strategic intent to bring about the state craft necessary for policy formulation, long-term resource allocation and implementation of electrification schemes.

The argument of the persistent role of the State, and government, in energy matters is supported by an extensive literature which points to the indispensability of central authority in assuring the availability, access to, and use, of energy. Stagliano (2001) indicates the important role of the United States National Energy Strategy, with its foremost attention to energy security,[37] which attests to the history of government intervention in "the entire regulatory cycle" [Pierce (2004, p. 57)]. Furthermore, the role of the State in managing electricity intensity has tended to expand in direct relation to the increasing use of energy [Horowitz (2004)]. This is not to say that the role of the government in energy is not changing in advanced countries as well as in developing countries [US DOE (2000)].

In relation to the vitally important national leadership and necessary political will, it should be noted that government efforts to electrify countries have historically taken about 40 to 60 years [Nye (1991)] of continuously incremental investment in capital accumulation (particularly in infrastructure) as well as in maintenance. This continual effort, while interrupted by exogenous factors (war, etc.,) was never abandoned by the successive governments (of different political colours) of the United States, the European countries or the former Soviet Union.[38] The role of the State has to be seen not just in terms of the returns to the electoral cycle, but also in terms of the distribution of risks over time.

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35 It must be recalled here that privatization of public or Government-owned assets is very recent in modern times. Starting in the 1980s with the United Kingdom conservative Government's privatization schemes. Even now the Government retains a strong regulatory role.

36 In the case of Russia, between 1880 and 1926, the ministries of finance, trade and industry and internal affairs; scientific and technical societies of engineers; and foreign capital, played an active role.

37 Interestingly, the energy crises of the 1970s promoted the establishment of the United States Strategic Petroleum Reserve; and the search for energy alternatives.

38 In other words, electrification of modern society was, over a long time, simultaneously a combination of political will and legislation (note the 1882 United Kingdom Electric Lighting Act and 1926 Electricity Supply Act, which created the United Kingdom Central Electricity Board), engineering education and technical advance, public finance support and competitive private entrepreneurship, social and cultural change. Such a combination resulted in exemplary utility companies (largely public in the United Kingdom and largely private in the United States), and a regulatory system that has passed through several economic permutations.

In general, whereas the public sector has a more robust appetite for long-term risk, the equity-oriented private entrepreneur has pay-back horizons that are brutally short. In the first instance, the public good argument is to the fore. In the latter, the fiduciary duty to shareholders holds sway. Given this dichotomy of public and private interests, and notwithstanding new technology and x-inefficiencies, the role of the State in the availability, access to, and productive use of, energy cannot be underestimated [Cook et al. (2004); Yang (2003)]. The concomitant of this is the importance of sequencing correctly the various policy instruments to maximise allocative efficiency. And for this to occur there has to be coherent plans created within stable decision-making structures and the institutions of State.

In examining the economic relations of energy, it is useful to distinguish between different forms of energy or, more precisely, sources of energy. The share of electricity in total energy use per capita in an empirical study of over 100 countries representing 99 per cent of global GDP, is highly correlated positively with GDP per capita in both scalar and vector terms [Ferguson, Wilkinson and Hill (2000)]. In other words, increases in level, and rate, of electricity use (as a proportion of total energy use) result in increases in GDP per capita and the rate of increase in GDP per capita. For the G7 countries[39] there is a very strong positive correlation between electricity's share of total energy use and GDP growth.

Findings by Ferguson, Wilkinson, and Hill (2000) also indicate that there is no correlation of total energy supply and GDP. In other words, it appears that, with respect to wealth creation, it is not how much energy an economy uses but what kind of energy it uses and the way the systemic organisation of its use creates more positive externalities over negative spillovers.

Furthermore, the strength of the positive correlation coefficient of electricity's share of total energy use per capita and GDP (at purchasing power parity) per capita for OECD countries is very robust and statistically significant at above 0.9. In sharp contrast, 75 per cent of non-OECD countries do not show any correlation. Among the countries with negative correlation coefficients, those with the strongest negative correlations (>-0.6) are all major oil-producers and exporters and developing countries (even though those of the Middle East have relatively high per capita incomes). The key conclusion for policy formulation is that the correlation between electricity use per capita and GDP per capita is stronger for rich economies and weaker for poor countries. Thus

[39] Canada, France, Germany, Italy, Japan, United Kingdom and United States.

the elasticity of the policy variable electricity/energy ratio is higher in industrialised countries; and therefore increasing the ratio has a greater effect on an industrialised country GDP than a similar increase in the ratio on developing country GDP. The key policy implication of this relationship is that developing countries have to work harder, in terms of the systemic organisation and information required, to realise the positive externalities of electricity use. The general policy implications related to the correlation are addressed further in Section 4 – Policy Advisory and Technical Co-operation Assistance, especially in relation to oil-endowed African countries.

2.1. Energy linked to economic growth

In general, there is strong evidence for a positive correlation between energy and economic growth (and vice versa). Even though the empirical approaches to this topic have different perspectives, the results are very similar. With respect to developing countries, Lee (2005, p. 417) presents a survey of empirical analyses, from 1985 to 2005 regarding results obtained from testing for causality on time series data sets covering from 22 to 46 years in 23 separate analyses. In this survey, eight empirical results indicate that energy use *causes* GDP growth, that is, income increases; four results indicate that GDP growth *causes* energy use; nine results reveal that the *causality* between energy consumption and income growth is bi-directional; and two results indicate that energy use and GDP growth are non-cointegrated (that is, not related according to the statistical methodology employed and other explanatory factors are not captured).

Controversy concerning the linkage between energy and growth has arisen when growth has been viewed strictly through a TFPG lens.[40] Nevertheless, in terms of the synergistic reinforcement of efficiency, growth, technological innovation and the structure of productivity growth, energy use results in GDP growth [Murillo-Zamorano (2005)]. One aspect that has been subsumed in the literature is the linkage between energy use and urbanisation in economic development. Jones (1989, p. 29) in analysing a group of 59 developing countries finds that "the elasticity of energy consumption with regard to a 1% increase in urbanisation is between 0.35 and 0.48". This implies that the said increase in urbanisation increases energy consumption by between 0.4 and 0.5 per cent. In relation to the direction of causality from energy to GDP growth [Stern and

[40] See, for example, Denison (1985) in which the energy crises of the 1970s had little significance in the evolution of productivity decline in OECD countries in the 1980s.

Cleveland (2004)] urbanisation is an important source of increased energy consumption. However, the contribution of urbanisation to the quality of GDP growth is crucially dependent on the systematic availability of, and access to, electricity.

Any remaining controversy over the role of electricity in economic development is dispelled when the structural determinants of energy demand are noted. In terms of World Bank income classification,[41] energy intensity (kg oil equivalent per US$ GDP) and structure of the economy, one finds that low- and high-income countries have almost the same energy intensities at 0.2 and 0.3, respectively. In contrast, lower middle- and upper middle-income countries have practically the same energy intensity at 0.48 - 0.49. However, whereas low-income countries have an economic structure in terms of percentage of GDP as: agriculture 31 per cent, industry 22 per cent, and services 41 per cent; high-income countries show a GDP structure of 3 per cent, 31 per cent and 65 per cent, respectively [Medlock and Soligo (2001, p. 81)]. Furthermore, lower and upper middle-income countries, for their part, show a GDP structure of 19 per cent, 30 per cent, 51 per cent; and 11 per cent, 34 per cent and 55 per cent, respectively.

The policy implications of electricity and economic structure are related to the non-monotonic relationship between per capita energy consumption and per capita GDP [Brookes (1973)]. That is, energy use rises with GDP until a certain point beyond which it falls even though GDP continues to rise.[42] Energy (electricity) must be available to power the economy to about US$4,000 income per capita per annum before the structure of the economy can take advantage of externalities to change to higher value adding transformations and transactions. Energy use affects structural change and technological adoption [Medlock and Soligo (2001)] and enables energy intensity to drop while the economy takes off.

Bocoum (2000) stresses the essential role of mineral and energy sectors in economic development because of their potential ability to establish 'thickly' intermediated industry inter-linkages and high output. Sectors with strong technological linkages with other sectors, as opposed to enclave sectors, are stimulating to economic growth and are, therefore, preferred by development planners. Toman and Jemelkova (2003) also concur that energy plays an essential role in developing a country's economy.

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41 In 1985, US$GDP per capita for low = US$0-1,000; lower middle US$1,001-3,000; upper middle US$3,001-10,000; and high > US$10,000.

42 The income elasticity of energy demand declines as income rises, and Galli (1998) finds the non-monotonic threshold to be approximately US$4,000 per capita per annum in the case of a panel of 10 Asian developing countries between 1973 and 1990.

Their work focuses more on the causality between the two by asking how important energy is to development. They list different channels that drive economic development and find that energy is important in so far as other development mechanisms are used simultaneously. By measuring energy poverty through the combination of two dimensions, access and quantity, Pachauri et al. (2004) find evidence of rapid economic development from energy use.

From the perspective of biophysical and economic theory, Stern and Cleveland (2004) examine the relationship between energy and economic growth with energy as a precondition for, and input to, production. They find empirically that energy impacts directly on GDP when variables, such as energy prices and other production inputs, are included in growth models. This work is particularly important for isolating key policy variables as energy use and GDP co-integrate and thus it is energy use that *causes* GDP growth (not vice versa). However, as the output/energy use ratio increases in the long-term as a function of the transition to electricity use, it is crucial to appreciate that the greater the use of energy in its thermodynamically efficient form, the higher the level of economic activity. Therefore, the role of energy in *causing* economic growth cannot be fully appreciated without understanding the role of energy as a production function (or input).[43] As indicated earlier, it is not energy per se but the information and organisation embodied in the efficient use of energy that causes economic growth. In this relationship it is electricity's share of total energy use that is key.[44]

This key finding that energy use, particularly electricity consumption, *causes* GDP growth is supported by earlier empirical research notably Burbridge and Harrison (1984) and Hamilton (1983). Due to decreasing energy use intensity, increasing TFPG, the energy transition and structural changes, there is a tendency for energy use and output to drift apart in the long-term [Stern and Cleveland (2004)]. Furthermore, in terms of the price of energy, the relationship between energy and GDP is asymmetric in that a rise in energy costs, via oil price shocks, has a larger GDP impact[45] than the corresponding fall

43 Standard macroeconomic theories have focused on capital and labour functions and, more recently, have included technology because modelling energy is not straightforward. Consequently, the role of energy in economic growth accounting has tended to be downplayed.

44 Energy use in the United States economy between 1973-1991 did not increase significantly in comparison with the significant increase in its GDP growth. Energy use increased by approximately 20 per cent in contrast to the 65 per cent increase in GDP. And generally, industrialized countries use 50 per cent less oil per dollar of GDP output compared to the mid-1970s (*The Economist*, 27 August 2005, p. 57).

45 The oil price hikes of 1973-1974, 1978-1980 and 1989-1990 were followed by worldwide recessions and rising inflation.

in energy cost [Hamilton (2003)].[46] Finally, energy (electricity) use in *causing* GDP is strongly correlated positively with the availability of energy.

With respect to synergies between different infrastructures, Willoughby (2002, 2004) provides a wide-ranging view of pertinent factors and variables. What appears crucially important is the finding that incremental investments in infrastructure are correlated with relatively rapid growth in countries at the top of the middle-income category enabling them to make the transition to lower energy intensity. In contrast, similar investments are correlated with relatively modest growth in low-income developing countries. The policy implication is that low-income developing countries have to work that much harder and smarter. The growth impact of public investment [Easterly and Rebelo (1993)] is found to be an increase of 0.60 per cent in the growth rate of GDP per capita from an additional 1 per cent of GDP invested into infrastructure. Willoughby (2002) cites empirical evidence for Brazil (1950-1995) in which investments in transport and energy infrastructure are most significant. Evidence from Mexico (1971-1991) points to the positive impact on manufacturing output from public investment in roads and electricity [Casteñeda, Cotler and Gutiérrez (2000)]. The correlation between electricity generating capacity, and paved roads, to returns on infrastructure investment is positive; with returns on infrastructure just below that of general capital over the period 1960-1990 [Canning and Bennathan (2000)]. This reflects the 14.2 per cent rate of return on public capital accumulation, which is marginally below the average return on private capital [Dessus and Herrera (2000)].

With reference to energy infrastructure, Pachauri and Spreng (2003) point to the relationship between access to, and use of, energy and poverty. In a major study of the socio-economic benefits of rural electrification, the World Bank (2002, p. 1) found that "rural electrification is often a preferred program for promoting equity and economic development in poor countries". The key conclusion of the study points to the synergies in infrastructure investments that amplify the benefits of electricity. From their study in rural India, Fan, Hazell and Haque (2000) estimate the correlation between agricultural production (and productivity) on the one hand, and infrastructure, technology and terms of trade variables on the other. The study concludes that there is a positive impact on agricultural growth and poverty alleviation from technology and improvements in infrastructure. Attention is paid by Pegg (2003) to the impact of dependency on export

[46] This could assist in explaining why the direction of causality from energy (electricity) use to GDP growth is reversed in the case of some developing countries, such as Indonesia (oil exporter) and Pakistan.

of natural resources. He points out that if a country is highly dependant on its resource export activities, this can have a negative impact on its economy. Economic growth in natural resource-dependent countries is even slower than in resource-poor countries. This has implications for policy in resource-rich developing countries, particularly those in sub-Saharan Africa.

The results of a policy of infrastructure investment, especially those which accentuate synergies in energy and transport systems are manifest as: (i) increases in the conduits for trade; (ii) reductions of risk and private uncertainty; (iii) increasing the sources of production inputs; and (iv) cushioning of exogenous shocks to the economy.

2.2. Electricity/energy linked to poverty reduction

In terms of specific linkages between electricity and poverty reduction, McDade (2004) finds that the use of low-load electricity does not necessarily contribute to the reduction in poverty unless the quality of fuels used by households and small industries improved. Hence, energy transition and efficiency, making fuel sources[47] more affordable and safe, lead to improved health and living conditions.

The Energy Sector Management Assistance Programme (ESMAP) of the World Bank [ESMAP (2003, p.1)], in answering the question of how modern energy services contribute to poverty reduction, tries to "explicitly define Country Action Plans for appropriate energy interventions in poverty reduction". It finds that enabling conditions of macro-economic and political stability, as well as a reduction in regulatory uncertainty and necessary energy reforms are key in attracting private investment. It is also important to enable policy to differentiate between the different needs of population and industry. Different needs call for different solutions. This requires high degrees of inter-ministerial co-ordination of policy formulation, policy measures and instruments.

The World Bank (ESMAP, 2000) in its Energy and Development Report 2000 draws a linkage between access to efficient, sustainable energy services and poverty alleviation in developing countries. Furthermore, the importance of sectoral reforms for enabling efficiency and improving access, and a 'pro-poor' energy reform agenda are emphasised. The World Energy Outlook 2002 also links electricity to poverty in its conclusion that lack of access to electricity -- and dependency on biomass -- are determinants of, and are positively correlated to, poverty and prevents poverty reduction.

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[47] Liquid petroleum gas would be such an alternative.

Again this points to the importance of the need for investments to enable the energy transition.

Pachauri and Spreng (2003) studied how access to, and use of, energy are related to poverty in rural India. The ability to access basic infrastructure, like tap water, and schooling, varies with the amount and the type of energy source used. They find that there is a greater difference in income levels between households that use different types of energy sources than between households that use the same type of source but in different amounts. The results of their study indicate the importance of the energy transition and making more energy accessible by the poor while redirecting energy use towards more efficient energy sources.

Meikle and Bannister (2003) explore the linkage between energy and poverty in poor urban households in developing countries.[48] They conclude that household energy consumption is a significant variable in the living conditions of the urban poor and that energy is necessary in order to be able to make socio-economic progress. Karekezi (2002a), in examining the linkage between poverty and energy in sub-Saharan Africa in particular, identifies growth in population and economy as the key drivers for the future of Africa's energy sector.

The positive correlation between electricity use and increasing income levels of rural populations is confirmed by Yang (2003) in a study on the impacts of electricity supply in China on economic development and poverty reduction. The reduction in the number of poor, from approximately 260 million (27.2 per cent of the population) in 1978 to some 30 million (2.3 per cent) in 2000, can partly be explained significantly by the extensive infrastructural development and the rural electrification schemes. There is a positive correlation between investments in electricity on the one hand, and per capita income and the number of poor, on the other.

The World Bank (2002) ESMAP report measured the effect of rural electrification on poverty in rural households in the Philippines. This extensive study on energy use and poverty shows a strong positive correlation which, in monetary benefit terms, is illustrated in Table 1 -- Summary of How a Typical Household in Rural Philippines Benefits from Electricity, 1998.

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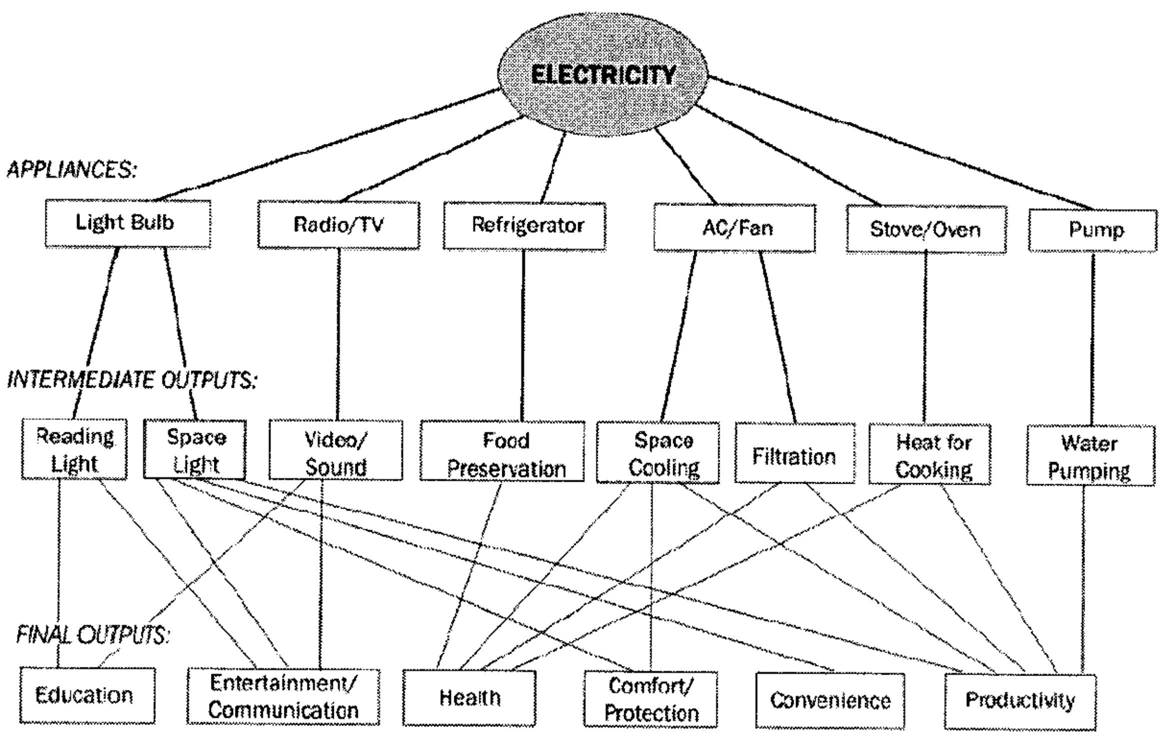
48 Indonesia, Ghana and China.

Table 1. Summary of How a Typical Household in Rural Philippines Benefits from Electricity, 1998		
Benefit category	**Benefit value (US dollars)**	**Unit (Per month)**
Less expensive and expanded use of lighting	36.75	Household
Less expensive and expanded use of radio and television	19.60	Household
Improved returns on education and wage income	37.07	Wage earner
Time savings for household chores	24.50	Household
Improved productivity of home business	34.00 (current business) 75.00 (new business)	Business

Source: ESMAP 2002.

Just as figure 1 indicates the macro-level matrix of linkages between energy and development, figure 2 -- Relationship Between Electricity Use and Energy Services -- below illustrates the specific links between electricity, technological devices and electric machinery, and beneficial outputs. Although figure 2 appears to show the obvious, what is missing is the linkage between government led provision of public goods, in this case, electricity generating capacity and transmission infrastructure, and direct benefits, as well as positive externalities. Classically, markets fail in technologically intense information. In particular, because certain technologies -- the so-called general-purpose technologies [Bresnahan and Trajtenberg (1995)] -- have widespread use across the economy, it is difficult for individual investors to capture all externalities. Hence large-scale investments tend to be limited, unless spearheaded by the public sector.

Figure 2. Relationship between electricity use and energy services



Source: ESMAP 2002.

Table 2 -- Summary of Electrification Benefits for Rural Households, 1998 -- below shows the results of the World Bank (2002) ESMAP study of the Philippines, quantified in monetary terms. While the study does not identify the entire capital cost of electrification, it is clear that there are substantial returns on public investment, as reflected in earlier work and studies of Canning and Bennathan (2000) and Dessus and Herrera (2000). One major implication of the table, in terms of energy transition and the change from low-, through middle-, to high-income development, is that "causal relations among energy use, energy prices, and economic activity indicate that efforts to slow carbon emission have a negative effect on economic activity" (Kaufmann, 2004, p.83). In turn, this implies that the imperative of sustainable development is of special significance in technical cooperation assistance of the international community and for relevant specialised agencies of the United Nations. Those with mandates dealing with energy-related technical assistance, in particular, have to enable a more rapid energy transition in order to bring about the reduction in energy intensity which is associated with economic growth and which carries with it prospects for diminishing negative externalities of reduced carbon emissions. This is not a trivial issue, as indicated by the policy implications of meeting the counter-balancing objectives of using energy to increase development and reducing the impact of burning fossil fuels on the global environment.

Table 2. Summary of electrification benefits for rural households, 1998

Less expensive and higher levels of lighting	$36.75	Per household per month	$147.50
Less expensive and higher levels of radio and television use	$19.60	Per household *per month*	$77.50
Adult education and electricity wage-income returns	$37.07	Per wage earner per month	$296.60
Time savings for household chores	$24.50	Per household per month	$97.50
Improved productivity for home business	$34.00 (existing home business, $75 (new home business	Per business per month	$24.70
Improved health	None	n.a.	n.a.
Improved agricultural productivity resulting in increased irrigation	None	n.a.	n..a
Feelings of security	Not quantified in monetary terms	n.a.	n.a.
Public-good benefits	Not quantified	n.a.	n.a.

Source: ESMAP 2002.

The World Bank (World Bank PRSP Sourcebook) has acknowledged the role of transport and energy in poverty reduction. In light of this, it has identified five policy goals for energy development that could have positive effects on poverty, namely, *expanding access to modern energy*, *improving the reliability of energy supply*, assuring fiscal sustainability, improving public sector governance, and reducing health and environmental costs.

2.3. Infrastructure linkages to poverty reduction and economic growth

As indicated earlier, the economic impact of energy use, in terms of electricity use, is enhanced and reinforced by its association with other infrastructure. Chatterjee et al. (2004) examine the impact of infrastructure on poverty reduction and find that infrastructure has a direct influence on poverty reduction, that is, if access to basic services, including electricity for the poor, is facilitated. This would subsequently lead to an increase in income-generation activities. The impact is further enhanced when set in a pro-poor policy environment. Similar findings are presented by Willoughby (2002) and Songco (2002) who indicate that the infrastructure sector should play a lead role in efforts to improve the productivity of the poor. They argue that infrastructure is connected to pro-poor growth in the following ways: (a) it spreads trade benefits to poor areas; (b) lowers the risk of private investment in agriculture and manufacturing; (c) makes it easier to deliver education and health services; and (d) reduces the risk associated with natural disasters.

The Asian Development Bank (ADB, 1999) has identified the lack of basic infrastructure as a key feature in the exclusion of the poor. In another study on infrastructure and poverty, Brenneman and Kerf (2002) find strong evidence that increased access to infrastructure services in the energy, water and sanitation, transportation, and information and communication sectors, has a strong impact on growth. This supports an earlier study on poverty by the ADB (2000), which concludes that electricity alone is not sufficient to increase development and growth across the board if other types of infrastructure, such as roads, safe domestic water supply, irrigation and telecommunications, are missing.

Stable institutions and good governance, a high degree of social capital and homogeneity among stakeholders are determinants of success in infrastructure projects. This concurs with Fan, Zhang and Zhang (2000) in their analysis of rural China where the positive effects of infrastructure investment in telecommunications (not possible without electricity), roads, and electricity, on growth and poverty reduction comes mainly through increased non-farm employment and improved wages in the agricultural sector. Yao (2003) indicates that the key role of infrastructure is in streamlining product and factor markets for extending opportunities to the poor. In Asia, the expansion of transport and logistic infrastructure at national level has allowed, through increasing efficiency gains, rapid access to global markets, which in turn has promoted economic growth and poverty alleviation.

Ahluwalia (2002), Ali and Pernia (2003), Jalan and Ravallion (2002), Kakwani and Pernia (2000), Kakwani (2000), and Pernia (2001, 2003) show that when investment in infrastructure is constrained, the poor seldom benefit from trade policy and institutional reform. The essential role of infrastructure for reducing poverty cannot be underestimated. And the impact of this missing link of energy infrastructure and other infrastructure is evidenced by significant subtractions from GDP. The USAID/SARI report (2003) in examining the economic impact of poor power quality on industry finds that unplanned interruptions in power supply result in substantial economic losses.[49]

The 2004 World Energy Outlook predicts that fossil fuels will continue to dominate the global energy mix and help meet increases in energy demand; and governments will be forced to continue funding infrastructure projects aimed at providing energy access to the poor. Of course, the problem is that raising finance will remain a challenge because the needs of poor countries are "larger relative to the size of their economies and because the investment risks are bigger" (IEA, 2004, p. 30). The report calls for research and development (R&D) efforts aimed at finding technological breakthroughs that could alter the manner in which energy is produced and used. Barnes et al. (2005) conducted the first worldwide assessment of the energy transition in urban households in developing countries. They find that energy transition, essential to rising prosperity, in which the poor can increasingly afford and use alternative forms of energy, from fuel wood, charcoal, kerosene, and coal, to fuels such as liquid petroleum gas, and electricity, is a major factor in economic development.

The empirical literature broadly confirms cross-sectionally and longitudinally that relationships between energy, electricity and economic development are positively correlated. The message is clear: economic advance is not possible without the widespread use of electricity. While the relationship between coefficients and elasticities may differ across the empirical evidence, overwhelming evidence points to industrial modernisation being dependent significantly on energy and electricity use.

Given the different energy and electricity variables, from the perspective of development in policy formulation, the unanswered questions are: which variable, which coefficient, and which elasticity should be incorporated into policy, and in what sequence

[49] In Bangladesh, for example, total losses amount to US$778 million a year and translate into 11.54 per cent of the industrial sector, or 1.72 per cent of national, GDP.

should the application of policy instruments and incentive switching occur? The next section attempts to provide reasonable answers to these questions.

Section 3 - Correlations and Models of Energy Use and Economic Development

This section is intended to identify, from the array of energy variables, key electricity variables in relation to factors of economic development with proxies, for example, by income, assets, etc. Such identification should assist in policy formulation and for designing appropriate incentive systems and for delivering policy advisory, technical co-operation and assistance (PATA) services. Appendix I shows the range of pertinent variables. Fourteen out of 17 independent energy variables correlate as expected sign with the dependent modernization variables. Thirty-six out of 52 independent variables also correlate as expected with the dependent poverty reduction variables. Appendix II shows the range of pertinent variables and the quantification of their relationships. These include correlations, elasticities, percentages and regression coefficients from the various empirical analyses that model significantly the relationship between energy, modernization and poverty reduction across OECD and developing countries.

Appendixes I and II provide powerful lenses for focusing on the most empirically relevant policy variables in the nexus between energy use, economic development and poverty reduction. The discussion that follows provides examples of energy regression coefficients (or, more accurately, energy elasticities of modernisation) for the purpose of elaborating policy prescriptions proposed in section 3. Appendixes I and II need to be read in tandem with their more concise version presented in table 3, and bearing in mind that 'Granger[50] causality' energy use *causes* GDP growth (Stern and Cleveland, 2004). Table 3 presents variables that have the strongest economic gearing or leverage.

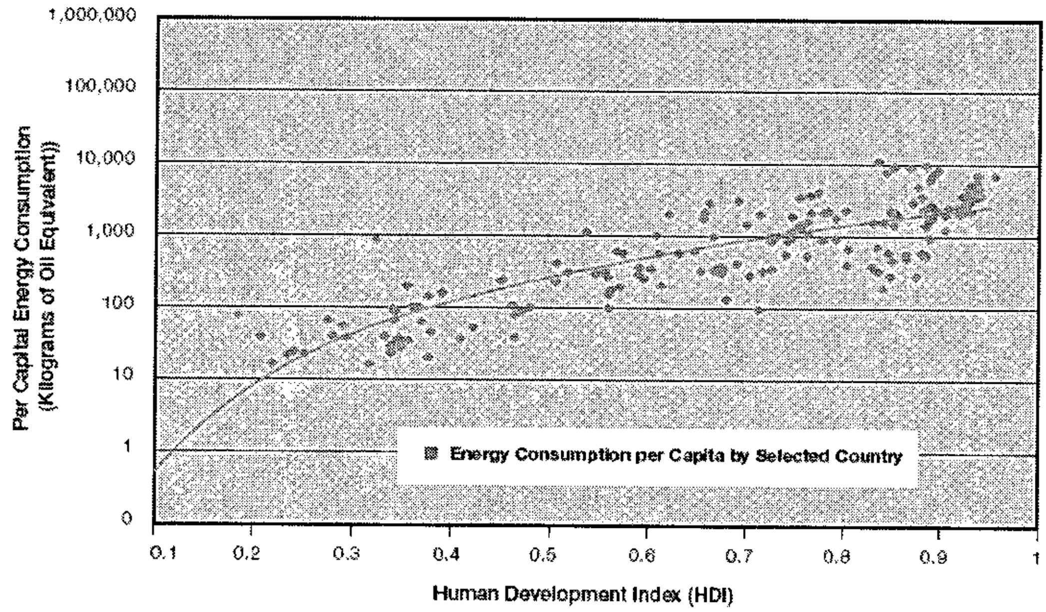
It is important, from the outset, to state that the purpose of statistical signification is to enable policy formulation taking into consideration statistical relationships embedded in regression coefficients. These coefficients have to be interpreted technically in order to see the impact of energy variables on modernisation

50 A means of testing the 'cause' in bivariate phenomena of whether there is a "direction of causality between two related variables" and whether there is feedback (Granger, 1969, p. 424). That is, a test for 'what comes first'; and in this case, energy use.

and poverty variables (and vice versa if no causality is construed). While this technical interpretation requires some understanding of statistics, the interpretation is absolutely crucial to PATA and for making right choices for policy formulation. The relationships and underlying interpretations are described in order to tease out the policy implications; in preference to tabular representation. The statistics are reported as found in the literature review and analysis to provide a perspective on how incremental the relationships are. And thus to confirm the fundamental idea that if the requisite and right policy choices are made and are then implemented effectively and efficiently, the cumulative results will be evident over the long term.

Electricity improvements can have a significant real impact on all aspects of poverty. However, this might be construed in terms of the importance of quality of infrastructure as opposed strictly to access to infrastructure. Yang (2003) finds that the impact of electricity supply in China through investments in rural electrification impacts economic development and poverty reduction in two different ways. First, there is a capital injection impact, which has a large effect on per capita income, especially in the relatively more highly-developed provinces. Secondly, there is an electricity supply impact, which largely reduces poverty especially in the relatively medium-income provinces. UN-Energy (2005) also stresses the key role that energy can play in improving the living conditions of the poor both through its direct effect on income, as well as its indirect effect on health, education, gender and environmental issues. Figure 3 shows the positive correlation between energy consumption and human development.

Figure 3. The positive link between energy consumption and human development



Source: UN-Energy (2005)

Electricity plays an important role in improving educational levels. The regression analysis for Thailand (Cook et al., 2004) shows a positive relationship between education levels and increases in the share of households that are electrified, the number of years of electrification, and expenditure on electricity bills. When taking into account solely poor households, the only variable of utmost significance is expenditure on electricity. Again, while causality is not tested for, it does seem that electricity usage has an impact on education (and not vice versa). Survey results show a distinct positive correlation; electricity helps people to study at night. Results for India were not as strongly positive as those for China where a stronger correlation is found between electrification and education.

Electricity can also have an effect on poverty through its impact on expenditure (Cook et al., 2004). Access to electricity is positively correlated with expenditure as it improves the life style of people through the use of electrical appliances. In Thailand, access to electricity increased expenditure for both poor and non-poor households. While electricity is used for consumption relative to productive investment, survey results corroborate the regression results since a majority of households show the impact on expenditure through increased use of electrical appliances. In terms of health-related benefits, electricity plays a key role through its positive impact on better food preservation, improved eye health, reduced heat stress from fan use and reduced indoor air pollution.

Other variables used to measure poverty include timesaving impacts, improved *safety/security, better access to information, access to common resources, and* electricity's effect on social capital. The most relevant and significant variable found in the Cook et al. (2004) study, which covers China, Thailand and India, is the impact of *electricity on safety and access to information.*

As mentioned earlier, the effect of general infrastructure investments on poverty reduction[51] can be of high importance due to the synergistic effects in reducing poverty derived from coupling transport and energy investments (Cook et al., 2004). When large segments of population are located away from improved roads, poverty is 58 per cent higher in non-electrified households than in electrified ones (Cook et al., 2004, p. 234).

For poverty reduction, per se, (Fan, Zhang and Zhang, 2000) in the case of China, investment in education has had the greatest impact, followed by rural telephones, agricultural R&D, and then roads and electricity, having approximately an equal effect. For agricultural productivity, R&D was most important, followed by education and rural telephones, with roads and electricity again in fourth and fifth places, respectively.

However, by estimating the correlation between agricultural productivity and infrastructure, Fan, Hazell and Haque (2000) conclude that there is a positive impact on agricultural growth and poverty alleviation from synergistic effects of technology and infrastructure improvements. For example, each additional rupees 1 million (approximately US$23,000) invested in electricity and other infrastructure reduces the number of poor by about nine people on average.[52] With respect to the positive correlation of electricity to production, the coefficient is on average 0.430. This implies that an electrification change of 1 per cent raises the production function by approximately 0.43 per cent, which is associated with an average of 6 per cent marginal

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[51] In a particularly useful analysis, Fan, Hazell and Thorat (1999) depict the positive correlations of public expenditure to growth and poverty reduction in India. Their results show that through a sequence of impacts, government spending on: agricultural R&D, roads, community development, and health has a significant impact on poverty reduction via specific mechanisms. These mechanisms are: TFP growth, prices, wages, land tenure and employment. The regression coefficients of expenditures to poverty average - 0.038. This can be interpreted as an elasticity for which the poverty elasticity of government spending is a change of about 1 per cent increase in public expenditure results in a 0.038 per cent reduction in poverty.

[52] The range of reduction in the number of poor is between 2 and 26 depending on locational factors. This relationship is what makes the continual incremental investment in energy infrastructure so crucial over a period of 40 to 60 years, especially when demographic vectors are taken into account.

return to investment in electricity infrastructure. The benefits of electricity are even stronger when considered in tandem with other infrastructure projects (Jones, 2004).

Murillo-Zamorano (2005) in reviewing the role of energy in productive growth finds that energy matters. Galli (1998) and Judson, Schmalensee and Stoker (1999) confirm that the income elasticity of energy demand declines as income rises. Evidently, as countries grow, a shift in the energy mix occurs. Medlock and Soligo (2001) show that as an economy proceeds through different stages of development it consumes more energy per capita.[53] How does this happen? The shift occurs from increased use of more efficient energy, usually in the form of electricity. In fact, the electricity/total energy use ratio increases with GDP per capita (Ferguson, Wilkinson and Hill, 2000; Rosenberg, 1998). However, total primary energy is less important at higher levels of development. All countries demonstrate a close relationship between electricity consumption per capita and GDP per capita with a correlation coefficient of at least 0.9 in industrialised countries; where as total primary energy per capita and GDP per capita "shows a much wider spread" (Ferguson, Wilkinson and Hill, 2000, p. 924).

The relevant correlations (regression coefficients and elasticities) between energy variables and industrial modernisation on the one hand, and energy variables and poverty on the other, are depicted in table 3.[54]

[53] More importantly, from a policy perspective, the share of final energy use, deriving from transportation, increases.

[54] For ease of interpretation, the relevant statistical technique is provided for all correlations, which are depicted as correlations, regression coefficients or elasticities. Such distinction is absolutely necessary for policy formulation because, ultimately, policy makers need to be aware of the effect that gearing (or leverage), an independent energy variable, has on a dependent economic growth (modernization) and/or poverty reduction variable. This is so that opportunity cost choices can be made coherently, in terms of industrial logic, public expenditure and the structure of incentive systems, to encourage the private sector to invest in the highly-regulated industry of energy services provision.

Table 3. Energy modernization and poverty reduction: regression coefficients				
Energy and modernization				
Dependent variable	**Independent variable**	**Reference**	**Coefficient**	**Finding***
Elasticities				
Energy consumption	Urbanization	Jones (1989)	0.35/0.48	+
Percentage of villages electrified	Total power expenditure	Fan, Hazell and Thorat (1999)	0.072	+
GDP	Energy use	Lee (2005)	0.44/1.54	+
Energy and poverty reduction				
Dependent variable	**Independent variable**	**Reference**	**Coefficient**	**Finding***
Logit				
Electricity access	Monthly household income	Komives, Whittington and Wu (2001)	0.271	+
Electricity access	Households owning their homes	Komives, Whittington and Wu (2001)	0.135	+
Electricity access	Households living in rural areas	Komives, Whittington and Wu (2001)	-1.981	-
Electricity access	Households living in low-income country	Komives, Whittington and Wu (2001)	-0.068	-
Electricity access	Households living under the poverty line	Komives, Whittington and Wu (2001)	-0.573	-
Probit				
Income-based poor	Per capita energy expenditure	Cooke et al. (2004)	-0.128	+
$1 per day poor (income)	Per capita energy expenditure	Cooke et al. (2004)	-0.253	+
Income-based poor	Electricity improvement	Cooke et al. (2004)	-0.392	+
$1 per day poor (income)	Electricity improvement	Cooke et al. (2004)	-0.215	+
Income-based poor	Access to electricity	Cooke et al. (2004)	0.236	-
$1 per day poor (income)	Access to electricity	Cooke et al. (2004)	0.501	-
Elasticities				
Agricultural growth	Rural electricity consumption	Fan, Zhang and Zhang (2000)	0.087	+
Share of non-agricultural employment	Rural electricity consumption	Fan, Zhang and Zhang (2000)	0.236	+
Labour productivity of agricultural worker	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	0.175	+
Share of non-agricultural employment	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	0.388	+
Land productivity	Electricity investments	Fan, Hazell and Haque (2000)	0.430	+
Marginal returns				
Per capita income	Rural power network investment (yuan 1 million)	Yang (2003)	1.250	+
Per capita income	Electricity consumption per GWh	Yang (2003)	0.10	+
Number of poor reduced	Electricity consumption per GWh	Yang (2003)	-5.08E-05	+
Poverty reduction	Electricity investments	Yang (2003)	-5.00E-04	+
Land productivity		Fan Hazell and Haque (2000)	5.45	+

* The sign of the finding indicates the effect the coefficient has on modernization or poverty reduction, that is, a + sign means that the coefficient increases modernization or poverty reduction; a – sign means a decrease in one of the dependent variables; and a = sign means no impact.

The literature review, analysis and appendixes I and II reveal several arrays of significant independent energy and energy-related variables. Each array is statistically related in a different way (methodologically) to the growth, modernisation and poverty reduction dependent variables. The list of significant independent energy and infrastructure coefficients in table 3 is too extensive to individually provide each gearing, or leverage, to each dependent growth, modernisation or poverty reduction variable.

Only the strongest variables are tested in an attempt to provide a picture of the choices available for policy formulation. Given the Granger causality (Stern and Cleveland, 2004) that energy use *causes* GDP growth, the gearing of policy formulation choices are given below.

3.1. Urbanisation → Energy consumption

Urbanisation, par excellence, depicts the modernisation of society. The variable selected by Jones (1989) has gearing such that a 1 per cent increase in urbanisation results in an increase in energy consumption of approximately 0.35 to 0.48 per cent.

3.2. Total power expenditures → Villages electrified

The correlation relationship of total power expenditures to the percentage of villages connected to the grid at 0.072 implies that a 1 per cent increase in expenditure on electricity leads to a 0.072 per cent increase in the percentage of villages electrified.

3.3. Energy use → GDP growth

The correlation relationship of energy use, in terms of kilotons equivalent of oil to GDP (indexed 1995=100), is such that a 1 per cent increase in energy use will create a rise of between 0.44 to 1.54 per cent with, and an average of 0.90 per cent rise in, the GDP index.

3.4. Household characteristics → Electricity access

Characteristics of households in developing countries correlate with access to electricity, and monthly average household income is positively correlated to electricity access. The correlation implies that a US$100 increase in household income increases the logistic (logit) regression coefficient of households gaining access to electricity by 0.271. This translates, in terms of odds[55] or chances, to the extent that the odds of having access to electricity increases by a factor of 1.31. There is also positive correlation of home ownership and electricity access (in terms of connection to grid). For home owners, the logit of electricity access is 0.135 times higher than for non-home owners. The result indicates that the odds of home owners having access to electricity are 1.14 times higher than for households that do not own their homes. With respect to bridging the urban-rural divide, the logit of access to electricity for rural households is 1.981 lower

[55] The logistic regression coefficient is transformed into odds by exponential raised to the power of that coefficient, that is, $e^{(0.271)} = 1.31$.

than for urban households. This means that the odds of rural households having access *to electricity are* 7.25 *times smaller than the odds for urban households.*

Furthermore, living in a low-income country is also negatively correlated to access to electricity. Households in a low-income country have a logit 0.068 lower than those in non low-income country. This indicates that the odds for households in low-income countries having access to electricity are 1.07 times smaller than the odds for households in non low-income countries. There is also a negative correlation between households below the poverty line and electricity access. The logit of poor households having electricity access is 0.573 smaller than those above the poverty line. This implies that the odds of households having access to electricity below the poverty line are 1.77 times lower than those above the poverty line.

3.5. Access to electricity → Income growth

The first measure of economic development in GDP terms of poverty is usually considered to be household income. Cook et al. (2004) find a positive and significant relationship between annual electricity bills and household income for China, although causality is not tested for in their analysis. Is it higher use of electricity that increases incomes, or is it the increase in income that allows higher electricity usage? For example, across a range of 20 variables (significant at the 1 per cent level) correlated with income-based poor and US$1 per day poor, electricity access carries coefficients of 0.236 and 0.501, respectively. These rank third and second among the 20 official provincial database variables. Similarly, across 18 field survey database variables (also significant at the 1 per cent level) the electricity improvement variable is negatively correlated at -0.392 and -0.215, with income-based poor and US$1 per day poor (ranking second and fifth), respectively. In other words, as the rate of electricity improvement increases, the number of income-based poor decreases.

An accurate interpretation of energy correlations, either as coefficients or elasticities, is an important policy issue because policy makers face opportunity costs of decision-making. The critical question, which has been alluded to earlier, is what energy variables (with what coefficients or elasticities of modernisation or poverty reduction) should be sequenced first into policy formulation (policy objectives and implementation)? Bearing in mind that the variable, income-based poor, represents the percentage of households below the national poverty line, and electricity access represents the percentage of households connected to the grid (Cook et al., 2004, p. 100), the correlation coefficients may be interpreted as follows.

Given the overwhelming thermodynamic evidence of energy use and output, in the first instance (of official provincial database), for every percentage increase in households connected to the grid, the probability of income-based poor and US$1 per day poor increases by 0.236 and 0.501, respectively. In the second instance (of field survey database), the same increase in grid connections results in the probability of the percentage of households per capita income below the national poverty line (income-based poor) and US$1 per day poor decreasing by 0.392 and 0.215, respectively.[56] In other words, the very poor may, with respect to the official provincial database, be unable to take sufficient advantage of electricity access without the presence of other infrastructure variables which produce synergies with energy infrastructure. With respect to the field survey database, electricity access in conjunction with other infrastructure leads to reductions in the number of poor.

This apparent contraindication may be explained further in terms of the dynamics of the short- and long-term relations between energy consumption and economic growth. According to Paul and Bhattacharya (2004) in the short term, commercial energy, usually in the form of electricity, acts as the engine of economic growth. In the long term, decreasing energy intensity and increasing TFP growth alters the causality. In other words, there is a Granger unidirectional causal relation from energy consumption to economic growth in the short run; and a long-run causal relation from GDP growth to energy consumption (Paul and Bhattacharya, 2004, p. 980) with causality being bi-directional in the medium term.

3.6. Energy and electricity expenditure characteristics → Poverty reduction

Expenditure on energy, and availability, access to and use of electricity are correlated to poverty reduction. The correlation of per capita expenditure with energy and wealth implies that with respect to income-based poor, and the US$1 per day poor, a 1 per cent increase in per capita energy expenditure results in the probability of the percentage of income-based poor and the percentage of US$1 per day poor decreasing by 0.128 and 0.253, respectively. It is a truism, but worth repeating, that spending on

[56] The contraindications of statistically significant results between official provincial data and field survey data in Cook et al. (2004, pp. 113-115) point to the critical value of choice of methodology and statistical analysis in policy research and analysis, as well as the need for high dependability on official data.

energy increases wealth. With respect to electricity improvement (that is, households in locations with a "reformed" electricity grid connection),[57] a 1 per cent increase in electricity improvements results in the probability of the percentage of households with per capita income below the national poverty line and US$1 per day poor decreasing by 0.392 and 0.215, respectively.

These results point to the benefits of reforming the energy and electricity sector by restructuring the system of incentives to secure increasingly reliable supply, and gain synergies with road and other infrastructure.

3.7. Energy consumption → Agricultural productivity and growth

Electricity consumption is correlated positively to growth in agricultural output, employment and agriculture sector productivity. The elasticities of the various relationships are: rural electricity consumption to agricultural growth, and share of non-agricultural employment, 0.087 and 0.236, respectively, consumption of rural electricity per rural worker to agricultural labour productivity, and share of non-agricultural employment, 0.175 and 0.388, respectively, and electricity investment to land productivity is 0.430. These elasticities imply that a 1 per cent increase in rural electricity consumption, per rural worker consumption, and electricity investments, respectively, will increase agricultural growth by 0.087 per cent, share of non-agricultural jobs by between 0.236 and 0.388 per cent, agricultural labour productivity by 0.175 per cent, and land productivity by 0.430 per cent. These gearings point to the necessity to make incremental investments continuously in electricity availability, access and use so that cumulative synergistic effects at both macro- and microeconomic levels can be achieved over time.

3.8. Rural power investments and electricity consumption → Wealth creation

Rural power investments and electricity consumption are positively correlated to per capita income effects. The linkages are such that increasing rural power investment by Yuan 1 million (approximately US$133,000) raises per capita income by approximately US$0.20; increasing electricity consumption in villages that are electrified reduces the number of poor by around 50 people; increasing rural power investment by Yuan 1 million reduces the number of poor by 500; investing rupees 1 million (approximately

[57] Associated with larger roads and more reliable supply.

US$23,000) in electricity infrastructure increases land productivity by approximately rupees 6 million per hectare.

The strength of the linkages between energy, and modernization and poverty reduction may be 'ranked' according to the statistical methodology employed to assist in policy choices under constraints[58] (see table 4).

Table 4. Ranking of policy variables

Rank	Dependent variable (V_d)	Independent variable (V_i)	Policy effect of V_i on V_d*
1	Electricity access	Decrease in rural households[59]	7.3 times more
2	Electricity access	Decrease in households below poverty line	1.8 times more
3	Electricity access	Increase in household income per month by US$100.	1.3 factor increase
4	Number of households below poverty line	Electricity improvement	0.4 less probable
5	Number of households with less than US$1/day income	Electricity improvement	0.2 less probable
6	GDP index	Energy use	0.9 per cent increase
7	Non-farm employment	Increase in rural electricity consumption per rural worker	0.4 per cent increase
8	Non-farm employment	Increase in rural electricity consumption	0.2 per cent increase
9	Poverty reduction	Increase in rural power network investment of US$133,000	500 less poor people

* Figures have been rounded off to one decimal place.

Besides, more than energy supply, it is continuous investment that will enable the transition to electricity. It is also the decisive element in economic development and industrialisation. However, hydrocarbon resource endowments seem to impede this process by limiting the drive of energy-rich countries for technical efficiency (Ferguson, Wilkinson and Hill, 2000; Bocoum, 2000; Pegg, 2003). An analysis of energy productivity,[60] defined as output divided by final energy use, across 24 industrialised and 32 developing countries (Miketa and Mulder, 2005, p. 443) indicates rankings for selected

58 Strictly, while only variables within the same statistical methodology may be ranked, under an assumption of equivalence, the 'ranking' provides another way to view policy variables in relation to options available to policy makers. Naturally, different groups of policy makers in different countries and localities may be severely constrained in different policy variables.

59 This is taken to be the same as an increase in urbanization.

60 The inverse of energy intensity and thus energy productivity is negatively correlated to energy intensity such that increases in energy productivity results in decreases in energy intensity.

international standard industrial classification sectors.[61] Non-OECD hydrocarbon-rich countries, and Mexico, all rank below thirty in energy productivity performance across selected sectors (with the exception of Mexico's third place in non-ferrous metals). This pattern has persisted over the 1975-1995 period, and is explained by the price of energy, the investment ratio and the energy mix, as well as technological diffusion being a local rather than a global phenomena (Keller, 2002).

Section 4 - Policy Advisory and Technical Co-operation Assistance (PATA)

The preceding extensive review and analysis confirm that energy use results in increasing income (Willoughby, 2004), and in the case of electricity, unlike other products generally, there is a strong argument that it is supply that creates demand. Despite arguments for economic liberalism in favour of "permitting markets to work rather than … 'planning'" (Robinson, 2000, p. 1), there are strong arguments for regulation. These reflect strategic issues alluded to in the introduction to this policy paper. These are basically security of supply, protecting against long-term price increases, safeguarding future generations, protecting the environment, moderating climate change and the *precautionary principle*.

It is within the framework of these arguments that UNIDO's technical cooperation services can be applied. Given the various strengths of positive correlation, that is, linkages between energy (electricity availability, access and use) and economic development (and poverty reduction) and, hence, industrial modernisation, the unanswered questions include: What are the policies and measures needed to enable those linkages to drive economic growth as rapidly as possible and render output effective and efficient? What should be the sequence for introducing policies? and What kind of architecture is required for the necessary incentivisation of economic agents involved? Satisfactory responses to these questions form the core of the international community's PATA to developing countries and countries with economies in transition.

From the outset, answers to the above questions have to be framed ultimately in terms of the political economy. Energy infrastructure and its associated policies are

[61] Food. Tobacco, textiles, leather; wood and wood products, paper, pulp and printing; chemicals, non-metallic minerals; iron and steel, non-ferrous metals, machinery; and transport equipment.

"essentially a struggle over who captures the considerable benefits of infrastructure services and who bears the costs" (ADB/JIBC/IBRD, 2005, p. xxviii). Furthermore, "the high economic benefits of infrastructure make a strong case for government intervention. So does the monopoly power that frequently accompanies the economies of scale required to deliver many infrastructure services" (ADB/JIBC/IBRD, 2005, p. xxviii).

Due to the nature of energy infrastructure, PATA is ultimately construed in terms of different combinations, or reformations, of public and private delivery of energy. This may be spatially and/or temporally sequenced, or concurrent, according to constraints (usually financial and technological) on government action. One note of caution is requisite in dealing with the political economy of energy. In the final analysis, it is not a matter of whether it is the public or private sector that delivers energy infrastructure and services, but rather the enabling environment that cradles that delivery. "An environment that's lousy for the private sector is equally lousy for the public sector" (ADB/JIBC/IBRD, 2005, p. xxix).

The relative success of the international community's PATA, specifically UNIDO's work, in germinating and taking root in institutions of the assisted country depends, to a large extent, on whether successive host governments have the requisite long-term economic vision and planning for the future, whether they can articulate an efficient incentive system economy-wide, or even have the strategic intent with respect to financing energy infrastructure in a sustainable manner. Given these preconditions, the possibility of PATA contributing to socio-economic development is advantageous; without them it is practically non-existent.

Figure 5 reveals the potential of PATA. There are two basic dimensions to the combination of public and private provision of energy within which UNIDO's catalytic PATA may be articulated. These are structural adjustment or privatisation of the energy industry along a spectrum of full regulation, through centralised planning by the State at one end, to full market liberalisation at the other.[62] There are, however, major implications for regulation and deregulation along this spectrum. According to Joskow and Tirole (2004, p. 47), with respect to reliability and competitive electricity markets,

[62] It must be recalled that it is fairly recently, that is, only since the early 1980s that the shift from 'regulation' to 'deregulation' occurred in OECD countries, and extended, through the structural adjustment programmes of the IBRD and IMF, to developing countries. The results can be mixed because of the dynamic complexity of trade-offs in the reduction and distribution of economic rents (Rothwell and Gómez, 2003; Alesina et al., 2003; Loayza, Oviedo and Servén, 2005; 2004).

"under certain contingencies the market price, and the associated scarcity rents available to support investments in generating capacity, are extremely sensitive to small mistakes or discretionary actions by the system operator. This is the 'knife-edge' problem". And in relation to current pressures for deregulation, in an analysis of winners and losers in electricity industry reforms which "critiques important elements of the 'Washington consensus' development policies" Haselip and Hilson (2005, p.1) conclude that,

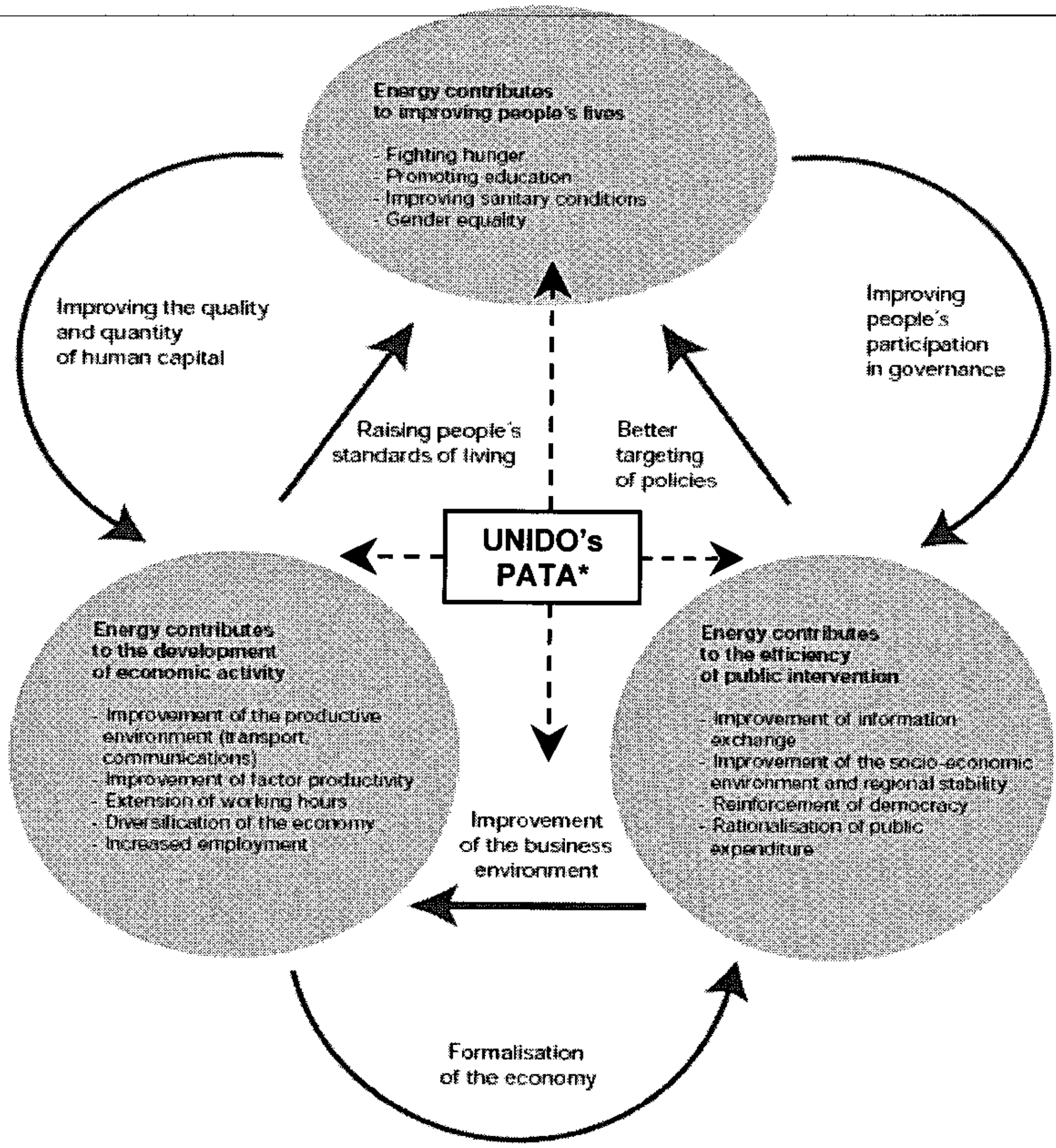
> "... given that nationalisation and protectionism of these same industries (electricity and mining sectors) is a key to their success and wider economic development in the West, it would appear unlikely that the privatisation of key national industrial could facilitate economic development in LDCs."
>
> (Haselip and Hilson, 2005, p. 11).

Furthermore,

> "... the successes of the liberalised markets in the West in steering electricity production towards better environmental performance and social equity have largely been due to effective (state) regulation." (Haselip and Hilson, 2005, p. 12).

In this context, figure 4 demonstrates UNIDO's PATA, which fits well into the matrix of links between energy and development (see also figure 1).

Figure 4. Matrix of links between energy and development



Source: adapted from OECD, African Economic Outlook (2003/2004), p.43.
* PATA (Policy Advisory and Technical Co-operation Assistance).

With respect to policy prescriptions to which UNIDO can contribute, there is a set of changes necessary to render the enabling environment fit to permit the benefits of regulation and market discipline to work through the economy of the energy sector and for positive externalities to be realised. The significant policy variables, referred to in section 2, translated directly into policy measures, would need to be applied in the following contexts (Saghir, 2005, pp. 10-18):

(i) Reducing institutional and regulatory barriers;

(ii) Extending access to the rural population;

(iii) Subsidizing capital costs for rural access;

(iv) Developing off-grid capacity;

(v) Extending access to the urban poor;

(vi) Financing up-front costs of connection;

(vii) Supporting appliance innovation at local level;

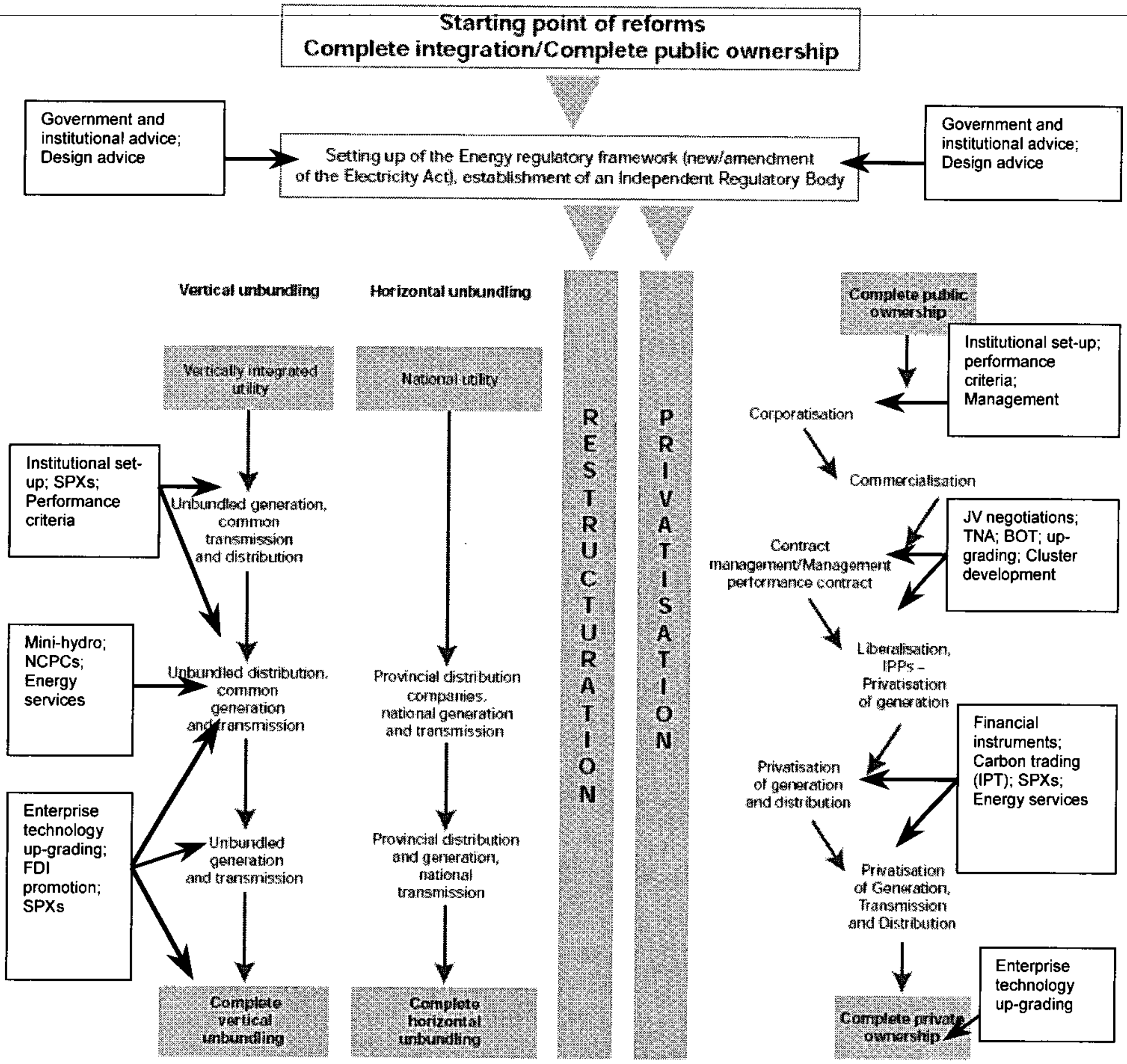
(viii) Reducing obstacles to interfuel substitution;

(ix) Preventing disproportionate costs burdens on the poor; and

(x) Supporting the poor during reforms.

UNIDO's interventions, bearing in mind the requirements of policy management, are illustrated in figure 5.

Figure 5. Possibilities for Policy Reform



Source: adapted from OECD, African Economic Outlook (2003/2004), p.47.
Note: UNIDO interventions are depicted in unshaded boxes.

The Department for International Development of the United Kingdom (2002) argues for the following: greater effectiveness in energy sector management, improved performance through well-sequenced privatization and regulatory reform, as well as expanding access, especially for the poor, by creating attractive conditions for private capital and appropriately targeting subsidies for the poor. Smith (2000) identifies a pro-poor regulatory strategy that focuses on deregulation, elimination of barriers to entry, reducing the scope and intensity of price controls. However, ensuring that the poor are not disproportionately burdened in this process is vital to preserving social stability.

Tunç, Çamdali and Parmaksizoglu (2006)[63] in examining Turkey's rapid industrialisation process, which requires significant amounts of energy, compare energy resources, capacity and electrical production and capacity with that of France, Germany and Switzerland. They argue that energy management is crucial to a developing country's future and anticipate that the optimal solution lies in diversifying the energy mix.

ESMAP (2000) in analysing Chile's rural electrification programme in 1994 points to different incentives to reduce market failures by subsidising, to some extent, private electricity distribution companies. The Energy and Development Report (ESMAP, 2000) refers to Chile's rural electrification programme as an example of a successful rural electrification project involving the participation of private companies in a relatively competitive environment.[64] The Haselip, Dyner and Cherni (2004) analysis of electricity market reforms in Argentina and their impact on poverty reduction conclude that the unbridled policies of the so-called 'Washington consensus' improved efficiency but were not effective in providing widespread access to electricity as the private sector had relatively few incentives to extend the infrastructure. This led to disproportionate costs to low-income consumers. They imply that policy reforms must take into consideration the fact that:

> "despite the huge efficiency gains made by privately run electricity distributors since reform, a large proportion of these benefits have gone to investors in the form of profits, the majority of which has been expatriated to Europe and the US." (Haselip, Dyner and Cherni, 2005, p. 12).

The Houskamp and Tynan (2000) study of private sector involvement in infrastructure provision for the poor find that even though private sector involvement is

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63 Report is available online in 2005.

64 In fact, the State funded 65 per cent of the total. However, the design was competitive and decentralized but based on central rules and homogenous interpretation given the State's involvement. It also provided solutions to energy needs by considering alternative technologies, and the role of the markets was limited to bidding competitions for Government funds to build up the energy infrastructure.

increasing in the poorest countries, the public sector is still responsible for most investment in infrastructure.[65]

Haselip and Hilson (2004) examine neo-liberal policies and argue that the context is of utmost importance for reforming such an essential sector as energy. The reforms promoted during the past 15 to 20 years have, according to Haselip and Hilson, not had the desired effect of easing socio-economic inequalities. The problems seem to lie in "industry-centric" policies that have tended to overlook the wider social context and thereby allowed – inadvertently -- enabling reforms to transfer the benefits from efficiencies gained to rich minorities. Fowdar (1999) in the analysis of the industrialisation of Mauritius concludes that it depended heavily on foreign investment and was supported by large surpluses in agricultural production. Kituyi (2004) suggests the life cycle approach as a tool with which more sustainability in production and consumption programmes can be achieved in a cost-effective way. In Africa, and many other developing countries, the extraction, processing and consumption of agricultural products and natural resources are connected with heavy losses of material and energy due to insufficient technological capability and lack of sustainability in policy formulation.

Webb & Derbyshire (2000) identify the high cost per consumer of extending existing electricity grids as the main problem in the provision of electricity services to rural areas. Therefore, they suggest that rural electrification in Africa should be part of a broader power-sector reform programme, which includes alternative forms in market structures, institutional arrangements, forms of ownership and use of technologies for energy production. LaRocco (2003) claims that the impact small and medium enterprises can have on an overall energy solution to poverty reduction is underestimated in that such enterprises are a major untapped resource for delivering modern energy.

UNIDO's catalytic inputs to the policy reform process depicted in figures 4 and 5 above link energy to development. In broad terms of PATA, investment, technology and functional disciplines are vital to industrialisation, given the thermodynamic basis of economic and industrial activity. In this regard, the negative correlation of oil-rich endowment to energy use is of particular importance to oil exporters of sub-Saharan Africa (SSA) and elsewhere, and hence, industrial strategies to assist in diversifying

[65] They also conclude that over 80 per cent of low-income countries have some type of private participation in infrastructure. This attests to the diffusion of liberalization policies across developing countries driven partly by lending and structural adjustment conditionalities imposed by the international financial institutions.

(counter intuitively) their hydrocarbon export economies are crucial. Reflecting on the strong arguments for regulation alluded to above; of even greater importance are schemes that safeguard the legacy of hydrocarbon endowments for future generations.[66]

From the findings presented in section 2, it can be concluded that it is extremely important to articulate policies that support the continuous incremental investments in energy infrastructure over time. The regulatory environment for energy also has to change over time to support the increasing availability of electricity. UNIDO is uniquely placed to assist in this effort.

Coefficients of household characteristics point to synergies in policy choices -- and policy-associated incentives -- that favour extending the rate of home ownership via reforms in the public housing sector.[67] Furthermore, increasing the rate of urbanisation is important -- not in terms of rural to urban migration -- but by ensuring that the services that hallmark modernisation are available locally. Pro-poor policies are absolutely vital to economic performance, and shifting the poverty line in terms of policy action is key.

In relation to connection to the grid, that is, from the electricity infrastructure power lines to junction boxes in households, this needs to be accelerated through schemes that enable the poor and very poor to amortise the costs involved over periods, and to reduce the financial burden involved. Also, the use of special financial instruments to assist in this process needs developing, enhancing and expanding. Here, the role of development banking across different economies of scale in financing is crucial.[68]

Given that energy use *causes* GDP growth, supporting efforts to industrialise, through the increased use of electricity -- but decreasing energy intensity -- confirms the focus of UNIDO's mandate on the development process. In this regard, UNIDO's relations with UN-Energy are vital and must be enhanced. The relationship between energy use and agriculture growth points to the continuing necessity for agri-business technical assistance. Concerning PATA, articulated in the Organization's strategy,[69] and

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66 See, for example, World Bank, 'Oil Revenues flow to Chad', 4 April 2005 for an indication that "Open since July 2003, the Chad-Cameroon Oil Pipeline has been operating under an unprecedented set of safeguards that is making sure the oil revenues is properly managed and used to reduce rampant poverty in Chad. A novel revenues distribution and management program adopted as law in 1999, broadly lays out that 10 per cent of oil revenues must be put aside and invested for future generations."

67 UNIDO's project work in low-cost housing is tangible evidence of assistance that facilitates home ownership.

68 See UNIDO, 2004a, An Examination of Emerging Financial Markets: Identifying Potential New Roles for UNIDO, Vienna: UNIDO, which describes ways and means to assist developing countries in this process.

69 See UNIDO, 2004b, Operationalizing UNIDO's Corporate Strategy: Services and Priorities for the Medium Term 2004-2007, Vienna: UNIDO, pp. 26-32 and pp. 48-52.

in relation to the broad development goals of industrialisation and the MDGs, UNIDO's services can be availed of optimumally. In particular, *inter alia*, the service modules on Investment and Technology Promotion, Private Sector Development and Sustainable Energy and Climate Change, are especially cogent to the policy variables in the foregoing review and analysis. In providing enabling services to developing countries, first, UNIDO's service modules would need to strengthen the industrial capacity of the energy sector.

Secondly, technical services would need simultaneously to assure sustainable and cleaner development (given the countervailing results of economic growth and the level of greenhouse gas emissions during early industrialisation transition).[70] UNIDO's PATA at government, institutional and enterprise levels maps well with the possibilities for policy reform as shown in figures 4 and 5. Given the oligopolistic structure of the energy industry, internationally and nationally, UNIDO would be best served, in terms of closer engagement with UN-Energy in policy and technical cooperation.[71] UNIDO's catalytic interventions could also consider judicious[72] and closer engagement with the policy thinking of international finance institutions (Feinstein, 2002; Bacon and Besant-Jones, 2002).

With special reference to hydrocarbon-rich SSA countries, UNIDO's continuing role in delivering technical assistance should focus over time periods on enabling the energy mix to undergo transformation as mentioned earlier in the preceding review and analysis. In this way, the transition towards more efficient forms of energy can reinforce enterprise upgrading, national cleaner production programmes, foreign direct investment and technology promotion. Also important in this regard is the necessity for UNIDO to support developing countries to bring science, technology and innovation, and their

70 See UNIDO, 2005, Annual Report 2004, Vienna: UNIDO, pp. 20-23 and pp. 19-20 for an articulation of how enabling services can be practically targeted to the policy variables in the preceding analysis of Section 3.

71 An analysis of the reports (web available) of the first four sessions of UN-Energy (2 July 2004, 12 December 2004, 15 March 2005 and 13 May 2005) no mention is made of UNIDO in session 1. Session 2, which deliberated the implication of higher oil prices, reports that (i) "UNESCO presented its in-depth paper on renewable energy" (Report of the Second Session of UN-Energy, Noordwijk, 12 December 2004); and (ii) "A note on UN-Energy Africa was circulated and UNIDO provided information on the mandate and goals of the group." Session 3, reported that "A concept paper will be submitted by UNIDO for consideration at the next meeting" also reported that "A revised concept paper on renewable energy was introduced by UNESCO". The Report of the Fourth Session (Jointly hosted by the IAEA and UNIDO) makes no specific mention of the UNIDO concept paper.

72 The recent power crisis in California "is so sudden and serious that it is prompting policymakers in many countries … to look for lessons that can be applied to the reform of their own power sectors." (See John Besant-Jones and Bernard Tenenbaum, 2001, The California Power Crisis: Lessons for Developing Countries, Energy and Mining Sector Board Discussion Paper, No.1, April, World Bank, p. 1).

knowledge-based institutions into the mainstream of policy thinking on energy for development.

UNIDO's support to national innovation systems on a continual basis is crucial if technology diffusion is to be accelerated and broadened. In all this, an essential balancing act is necessary. This concerns the difficult trade-off between increasing energy use in a variety of efficient forms and greenhouse gases, pollution (local, global) and climate change. This trade-off involves transaction costs that have to be financed, some way or the another. In order to help lower transaction costs, UNIDO's technical expertise is called for in financial, managerial, technological and, most importantly, organizational intermediation.

Section 5 - Concluding Remarks

This paper has reviewed and analysed the empirical basis of policy thinking regarding energy (in particular, electricity) industrial modernization and poverty reduction. The review and analysis are fairly extensive -- but not exhaustive -- in order to select the significant policy variables. The policy advisory and technical co-operation activities are tapered and avoid being prescriptive, for good reason, because particular circumstances of developing countries are very different. This latter section sets UNIDO's technical cooperation within a framework that is broadening due to the dynamically complex interlinkages between energy, industrial modernisation and economic growth.

The message is simple: there is no incidence of economic development and growth without expanding the use of increasingly efficient forms of energy to power society. While this may seem blindingly obvious, the difficult task is that of identifying the different gearing effects that different energy variables have on GDP growth and its proxies. Hence, there are different options and combinations of policy choices that have to be formulated by policy makers in accordance with particular circumstances of the locality, country and region in question. The review and analysis also demonstrate unequivocally that without continuous incremental capital and operational investment (usually with government and public sector in the lead) over an extended period, approximately 50 years, electrifying a country is virtually impossible.

Developing countries lack the funds and technical capacity and, in many cases, the stable political economy conditions to achieve this. The nature of energy is such that market forces have, at least initially, limited capabilities to meet needs at national level. Government provision of the public good of electricity and the necessary public goods supplied by specialised agencies, such as UNIDO, to support governments will continue to be required over the long term if developing countries are to improve the living conditions and wealth of their citizens.

The review and analysis also indicate by implication, that the latest vintages of capital (technology)[73] will continue to lie beyond the reach of developing countries, unless interventions are made to alter the availability/price terms of technology and technology diffusion in conjunction with other technical cooperation assistance. UNIDO has a vitally important catalytic role to play in this.

As with any policy paper, there can be areas of interest in which the level of knowledge is limited. Further research is definitely required to redress the situation even though literature on energy and development is vast and growing. A casual examination of the independent variables, as presented in appendixes I and II, shows either aggregate level data or household and employment level data. Industry, sector and sub-sector variables, by and large, are not as adequately represented as expected with the exception of Miketa and Mulder (2005). Greater attention in this area, especially with regard to comparative analysis of the developing country sector energy intensities in relation to technology upgrading and investment, is necessary.

Finally, the empirical evidence of different sets of longitudinal panel data, between 20 and 40 years, confirms of the role of energy with GDP growth. This creates a major implication for governance, to the extent that the results of current and future policy action cannot be measured meaningfully. It is therefore necessary for developing countries to record meticulously over time the relevant statistics for policy analysis and research to disclose error and confirm correct choices in that policy action.

73 The problem is that advances in technology tend to be embodied in the latest "Vintages of Capital" (Greenwood and Jovanovic, 1998, p. 2).

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Appendices

APPENDIX I

Correlation between Energy, Modernisation and Poverty Reduction: General Impacts

++ Strong Positive Impact
+ Positive impact
- Negative Impact
+/= Low positive/ No impact
= No Impact

Dependant Variable	Independent Variable	Reference	Finding
ENERGY AND MODERNISATION			
GDP/capita	Electricity Consumption/Capita	Ferguson, Wilkinson and Hill (2000)	+
GDP/capita	Electricity/Energy ratio	Ferguson, Wilkinson and Hill (2000)	+
GDP	Energy Use	Stern and Cleveland (2004), Stern (2000)	+
GDP	Energy Use	Lee (2005)	+
Share of final energy used toward transportation	GDP/Capita	Medlock and Soligo (2001)	+
Share of final energy used toward residential and commercial activities	GDP/Capita	Medlock and Soligo (2001)	+
Share of final energy used toward industrial activities	GDP/Capita	Medlock and Soligo (2001)	-
Economic Development	Availability of energy services	Toman and Jemelkova (2003)	+
GDP/capita	Energy consumption	Brookes (1973)	+
Productivity growth	Energy Consumption	Murillo-Zamorano (2005)	+
Urbanisation	Energy consumption	Jones (1989)	+
Productive hours	Electric lighting	Fan, Hazell and Haque (2000)	+
Human Development Index	Energy Consumption/ Capita	UN-Energy (2005)	+
Percentage of villages electrified	Total Power Expenditures	Fan, Hazell and Thorat (1999)	+
GDP/capita	Total primary energy supply	Ferguson, Wilkinson and Hill (2000)	=
Income	Energy Demand	Brookes (1973) Galli (1998), Judson, Smalensee and Stoker (1999)	=
Share of Electricity in Total Energy use	Energy Intensity	Rosenberg (1998)	-
ENERGY AND POVERTY REDUCTION			
Electricity access			
Thailand Case Study	Household expenditure	Cook et al. (2004)	+
	Household Education	Cook et al. (2004)	+
	Household Health	Cook et al. (2004)	+
	Free time availability	Cook et al. (2004)	+
	Safety	Cook et al. (2004)	+
	Access to information	Cook et al. (2004)	+
	Bonding social capital	Cook et al. (2004)	+
	Bridging social capital	Cook et al. (2004)	+
India Case Study	Change in Household Health	Cook et al. (2004)	+
	Change in Safety levels	Cook et al. (2004)	++
	Change in Information access	Cook et al. (2004)	+
	Expenditures per capita for households living near road	Cook et al. (2004)	+
China Case Study	Share of income from wage or slaried employment	Cook et al. (2004)	+
	Per capita income	IEA (2002)	+
China	Agricultural growth	Fan, Zhang and Zhang (2000)	+
	Share of Non-agricultural employment	Fan, Zhang and Zhang (2000)	+

Dependant Variable	Independent Variable	Reference	Finding
Poverty reduction			
India Case study	Per capita energy expenditure	Cook et al. (2004)	+
China Case Study	Electricity improvement	Cook et al. (2004)	+
	Electricity use	Saghir (2005)	+
China	Public Electricity Investment	Fan, Zhang and Zhang (2000)	+
	Government expenditures on Electricity	Fan, Zhang and Zhang (2000)	+
India	Impact of electrification	Fan, Hazell and Haque (2000)	+
Income			
Thailand Case Study	Annual electricity bill for all rural households	Cook et al. (2004)	+
	Annual electricity bill for poor rural households	Cook et al. (2004)	+
China	Rural Power Network Investment	Yang (2003)	+
Thailand	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	+
	Monthly Household Income	Komives, Whittington and Wu (2001)	+
	Households owning their homes	Komives, Whittington and Wu (2001)	+
Expenditure			
Thailand Case Study	% change of electrified households	Cook et al. (2004)	+
	Years since Household was electrified	Cook et al. (2004)	+
	Annual electricity bill for poor rural households	Cook et al. (2004)	+
Education			
Thailand Case Study	% all rural village households electrified	Cook et al. (2004)	+
	Years since all rural Household was electrified	Cook et al. (2004)	+
	Annual electricity bill	Cook et al. (2004)	+
Electricity access			
Thailand Case Study	Occupational change	Cook et al. (2004)	=
	Household income	Cook et al. (2004)	=
	Household Debt	Cook et al. (2004)	=
	Acess to common resources	Cook et al. (2004)	+/=
India Case Study	Change in Household Income	Cook et al. (2004)	+/=
	Change in Household Education levels	Cook et al. (2004)	=
	Time savings	Cook et al. (2004)	=
	Change access to common ressources	Cook et al. (2004)	=
	Change in bonding social capital	Cook et al. (2004)	=
	Change in binding social capital	Cook et al. (2004)	=
	Expenditures per capita for households not living near road	Cook et al. (2004)	=
China Case Study	Share of income from wage or slaried employment	Cook et al. (2004)	=
	Access to electricity	Cook et al. (2004)	-
Poverty reduction			
India Case study	*Interactive effects between electricity and* transport	Cook et al. (2004)	-
China Case Study	Access to electricity	Cook et al. (2004)	-
Income			
Thailand Case Study	% poor rural village households electrified	Cook et al. (2004)	-
Education			
Thailand Case Study	% poor rural village households electrified	Cook et al. (2004)	=
	Years since poor rural Household was electrified	Cook et al. (2004)	=

APPENDIX II

Energy, Modernisation and Poverty Reduction: Correlation Coefficients

NS = not significant

* Regression Coefficients

** The sign of the finding indicates the effect the coefficient has on modernisation or poverty reduction. I.e. a + sign means that the coefficient increases modernisation or poverty reduction; a - sign means a decrease in one of the dependent variables; and a = sign means no impact.

ENERGY AND MODERNISATION

Dependent Variable (only for regressions)	*Independent Variable (only for regressions)*	*Reference*	*Coef*	*Finding***
GDP/capita	Electricity Consumption/Capita	Ferguson, Wilkinson and Hill (2000)		+
	Asia		0.999	
	OECD		0.998	
	Latin America		0.803	
	Non-OECD Europe		0.791	
	Africa		-0.130	
	Middle East		-0.816	
GDP/capita	Electricity/Energy ratio	Ferguson, Wilkinson and Hill (2000)		+
	OECD		0.988	
	Asia		0.948	
	Latin America		0.739	
	Non-OECD Europe		0.039	
	Africa		-0.410	
	Middle East		-0.836	
GDP	Energy Use	Stern and Cleveland (2004), Stern (2000)		+
GDP	Energy Use	Lee (2005)[a]		+
GDP/capita	Energy consumption	Brookes (1973)		+
Productivity growth	Energy Consumption	Murillo-Zamorano (2005)		+
Energy consumption	Urbanisation	Jones (1989)[a]	0.35*/0.48*	+
Human Development Index	Energy Consumption/capita	UN-Energy (2005)	*	+
Percentage of Villages electrified	Power Expenditures	Fan, Hazell and Thorat (1999)[b]	0.072*	+
Share of Energy consumption used toward transportation	GDP/Capita	Medlock and Soligo (2001)[c]		+
Share of Energy consumption used toward Residential and Commercial Activities	GDP/Capita	Medlock and Soligo (2001)		+
Share of Energy consumption used toward industrial activities	GDP/Capita	Medlock and Soligo (2001)		-
Share of Electricity in Total Energy consumption	Total energy consumption / GDP	Rosenberg (1998)		-
	Electricity Share in US in 1899		5%	
	Electricity Share in US in 1985		40%	
	Energy Intensity Index in 1899		260	
	Energy Intensity Index in 1985		80	
GDP/capita	Total primary energy supply/capita	Ferguson, Wilkinson and Hill (2000)		=
	Asia		0.998	
	Non-OECD Europe		0.972	
	Latin America		0.933	
	OECD		0.705	
	Africa		0.063	
	Middle East		-0.711	
Income	Energy Demand	Brookes (1973) Galli (1998), Judson, Shmalensee and Stoker (1999)		=

ENERGY AND POVERTY REDUCTION				
Dependant Variable	***Independent Variable***	***Reference***	***Coef***	***Finding***
Electricity Access	Monthly Household Income	Komives, Whittington and Wu (2001)[d]	0.271*	+
Electricity Access	Households owning their homes	Komives, Whittington and Wu (2001)	0.135*	+
Telephone Access	Montly Household Income	Komives, Whittington and Wu (2001)	0.217*	+
Sewer Access	Montly Household Income	Komives, Whittington and Wu (2001)	0.075*	+
Per capita income	Electricity Access	IEA (2002)		+
Agricultural growth	Rural electricity consumption	Fan, Zhang and Zhang (2000)[e]	0.087*	+
Share of non-agricultural employment	Rural electricity consumption	Fan, Zhang and Zhang (2000)	0.236*	+
Wage rate of agricultural labor	Rural electricity consumption	Fan, Zhang and Zhang (2000)	0.096*	+
Agricultural growth	Average years of schooling	Fan, Zhang and Zhang (2000)	NS	+
Agricultural growth	Number of rural telephone sets	Fan, Zhang and Zhang (2000)	0.049*	+
Agricultural growth	Government expenditures on R&D	Fan, Zhang and Zhang (2000)	0.304*	+
Agricultural growth	Road density	Fan, Zhang and Zhang (2000)	0.295*	+
Agricultural growth	*Percentage of irrigated areas*	*Fan, Zhang and Zhang (2000)*	*0.107**	+
Share of non-agricultural employment	Road density	Fan, Zhang and Zhang (2000)	0.219*	+
Share of non-agricultural employment	Number of rural telephone sets	Fan, Zhang and Zhang (2000)	0.053*	+
Share of non-agricultural *employment*	Average years of schooling	Fan, Zhang and Zhang (2000)	0.114*	+
Share of non-agricultural employment	Growth in Non-agricultural GDP	Fan, Zhang and Zhang (2000)	0.583*	+
Labor productivity of agricultural worker	Irrigation stock generated from government	Fan, Jitsuchon and Methakunnavut (2004)[f]	0.099*	+
Labor productivity of *agricultural worker*	Stocks of Agricultural R&D	Fan, Jitsuchon and Methakunnavut (2004)	0.464*	+
Labor productivity of agricultural worker	Years of schooling	Fan, Jitsuchon and Methakunnavut (2004)	8.63*	+
Labor productivity of agricultural worker	Length of rural roads	Fan, Jitsuchon and Methakunnavut (2004)	0.140*	+
Labor productivity of agricultural worker	Rural Telephone sets per agricultural worker	Fan, Jitsuchon and Methakunnavut (2004)	0.272*	+
Labor productivity of agricultural worker	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	0.175*	+
Share of non-agricultural employment	Urban GDP / Capita	Fan, Jitsuchon and Methakunnavut (2004)	2.97*	+
Share of non-agricultural employment	Length of rural roads	Fan, Jitsuchon and Methakunnavut (2004)	0.820*	+
Share of non-agricultural employment	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	0.388*	+
Share of non-agricultural employment	Years of schooling	Fan, Jitsuchon and Methakunnavut (2004)	NS	+
Share of non-agricultural employment	Rural Telephone sets per agricultural worker	Fan, Jitsuchon and Methakunnavut (2004)	NS	+
Income based poor	Per capita energy expenditure	Cook et al. (2004)[g]	-0.128*	+
$1/day poor (income)	Per capita energy expenditure	Cook et al. (2004)	-0.253*	+
Income based poor	Electricity improvement	Cook et al. (2004)	-0.392*	+
$1/day poor (income)	Electricity improvement	Cook et al. (2004)	-0.215*	+
Per capita income	Rural Power Network Investment (One million Yuan)	Yang (2003)[h]	1.25*	+
Number of poor reduced per 10,000 Yuan	Government expenditures on education	Fan, Zhang and Zhang (2000)	6.30	+
Number of poor reduced per 10,000 Yuan	Government expenditures on rural telephones	Fan, Zhang and Zhang (2000)	4.02	+
Number of poor reduced per 10,000 Yuan	Government expenditure on R & D	Fan, Zhang and Zhang (2000)	3.36	+
Number of poor reduced per 10,000 Yuan	Government expenditure on rural roads	Fan, Zhang and Zhang (2000)	2.96	+
Number of poor reduced per 10,000 Yuan	Government expenditure on electricity	Fan, Zhang and Zhang (2000)	2.92	+
Number of poor reduced per million rupees	*Expenditures on Roads*	*Fan, Hazell and Haque (2000)*	*8.02*	+

Dependant Variable	*Independent Variable*	*Reference*	*Coef*	*Finding*
Number of poor reduced per million rupees	Impact of electrification	Fan, Hazell and Haque (2000)	1.56	+
Number of poor reduced per million rupees	Adoption of High-yielding varieties of food	Fan, Hazell and Haque (2000)	0.76	+
Number of poor reduced per million rupees	Impact of increased education	Fan, Hazell and Haque (2000)	0.48	+
Number of poor reduced per million rupees	Expansion of canal irrigation	Fan, Hazell and Haque (2000)	0.46	+
Number of poor reduced per million Bhat	Consumption of rural electricity per rural worker	Fan, Jitsuchon and Methakunnavut (2004)	276.07	+
Number of poor reduced per million Bhat	Stocks of Agricultural R&D	Fan, Jitsuchon and Methakunnavut (2004)	138.10	+
Number of poor reduced per million Bhat	Length of rural roads	Fan, Jitsuchon and Methakunnavut (2004)	107.23	+
Number of poor reduced per million Bhat	Years of schooling	Fan, Jitsuchon and Methakunnavut (2004)	22.75	+
Per capita income	Rural Power Network Investment (One million Yuan)	Yang (2003)	1.250	+
Per capita income	Electricity consumption per GWh	Yang (2003)	0.10	+
Number of poor reduced	Electricity consumption per GWh	Yang (2003)	-5.08E-05	+
Poverty reduction	Rural power network investment (One million Yuan	Yang (2003)	-5.00E-05	+
Land Productivity	Electricity Investments	Fan, Hazell and Haque (2000)	5.45	+

Dependant Variable	*Independent Variable*	*Reference*	*Coef*	*Finding*
Income based poor	Access to electricity	Cook et al. (2004)	0.236*	-
$1/day Poor (income)	Access to electricity	Cook et al. (2004)	0.501*	-
Electricity Access	Households living in rural area	Komives, Whittington and Wu (2001)[d]	-1.981*	-
Electricity Access	Households living in Low income country	Komives, Whittington and Wu (2001)	-0.068*	-
Electricity Access	Households living under the poverty line	Komives, Whittington and Wu (2001)	-0.573*	-
Telephone Access	Households living in rural area	Komives, Whittington and Wu (2001)	-1.58*	-
Telephone Access	Households living in Low income country	Komives, Whittington and Wu (2001)	-1.059*	-
Telephone Access	Households living under the poverty line	Komives, Whittington and Wu (2001)	-0.582*	-
Sewer Access	Households living in rural area	Komives, Whittington and Wu (2001)	-3.003*	-
Sewer Access	Households living in Low income country	Komives, Whittington and Wu (2001)	-0.735*	-
Sewer Access	Households living under the poverty line	Komives, Whittington and Wu (2001)	-0.634*	-

a - Elasticity form
b - Double-log functional forms for all equations
c - Two-stage least squares approach
d - Logistic regression coefficients from Multivariate Analysis
e - Double-log functional forms for all equations
f - Double-log functional forms for all equations
g - Probit
h - Linear-Least square regression model

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